UNIVERSITY OF ILLINOIS
LIBRARY

Class Book Volume
550.5 FI 1

GEOLOGY GEOLOGY GEOLOGY
NAT. HIST. GEOLOGY

Je 07-10M

Return this book on or before the *Latest Date* stamped below. A charge is made on all overdue books.

U. of I. Library

UNIVERSITY OF
ILLINOIS LIBRARY
AT URBANA-CHAMPAIGN
GEOLOGY

MAR 2 1941
18 APR 1951
OCT 4 1958
AUG 29 1960
DEC 31 1962
NOV -7 1963
NOV 29 1966
DEC 17 1976
DEC 15 1976

17625-S

LIBRARY U. OF I. URBANA-CHAMPAIGN

GEOLOGY

Digitized by the Internet Archive
in 2021 with funding from
University of Illinois Urbana-Champaign

https://archive.org/details/geologicalseries1189unse

I
not o
[illegible] i cat.

LIBRARY
OF THE
UNIVERSITY of ILLINOIS.

693
27no9

PUBLICATIONS
OF THE
FIELD COLUMBIAN MUSEUM

GEOLOGICAL SERIES

Volume I.

Chicago, U. S. A.
1895–1902

550.5
FI
v.1

Geology

19 N '07 Recd.

TABLE OF CONTENTS.

PAGES.

Handbook and Catalogue of the Meteorite Collection.
O. C. Farrington. (Plates I–IV.) 1– 66

Observations on Popocatepetl and Ixtaccihuatl, with a Review of the Geographic and Geological Features of the Mountains.
O. C. Farrington. (Plates VII–XVIII.) 67–120

The Ores of Colombia, from Mines in Operation in 1892.
H. W. Nichols. (Plate XIX.) 121–177

The Mylagaulidæ, an Extinct Family of Sciuromorph Rodents.
E. S. Riggs 178–187

A Fossil Egg from South Dakota.
O. C. Farrington. (Plates XX–XXI.) 188–200

Contributions to the Paleontology of the Upper Cretaceous Series.
W. N. Logan. (Plates XXII–XXVI.) 201–216

New Mineral Occurrences.
O. C. Farrington 217–231

Crystal Forms of Calcite from Joplin, Missouri.
O. C. Farrington. (Plates XXVII–XXXI.) 232–241

Observations on Indiana Caves.
O. C. Farrington. (Plates XXXII–XXXIII.) 242–266

The Dinosaur Beds of the Grand River Valley of Colorado.
E. S. Riggs. (Plates XXXIV–XXXIX.) 267–274

The Fore Leg and Pectoral Girdle of Morosaurus, with a Note on the Genus Camarosaurus.
E. S. Riggs. (Plates XL–XLII.) 275–281

Meteorite Studies.—I.
O. C. Farrington. (Plates XLIII–XLVI.) 282–315

Index 316–323

110 '07 BINDING 1-15

3

102127

FIELD COLUMBIAN MUSEUM
PUBLICATION 3.
GEOLOGICAL SERIES VOL. I. NO. I.

HANDBOOK AND CATALOGUE

OF THE

METEORITE COLLECTION.

BY

OLIVER C. FARRINGTON, PH. D.,
Curator, Department of Geology.

CHICAGO, U. S. A.
August 1895.

PREFACE.

The care with which meteorites are treasured and the value they have assumed in the hands of collectors renders it desirable that as full information as possible should be available regarding the whereabouts of each specimen. To furnish this information in regard to the collection of meteorites of the Field Columbian Museum has been the principal object in issuing this publication.

It is also hoped, however, that a more thorough study of the collection will be facilitated by the Catalogue and that that portion of the work called the Handbook, when used in connection with the specimens, will enable any one not previously acquainted with the subject to gain some knowledge of the principal characters of meteorites.

Many of the statements of this portion of the work, for which it has not been practicable to give specific credit,have been drawn from authors whose works are mentioned at the end of the Handbook.

Prof. L. Fletcher's work, *An Introduction to the Study of Meteorites, edition of 1890*, has been found especially helpful and its plan of arrangement is so excellent that it has been largely followed by the author.

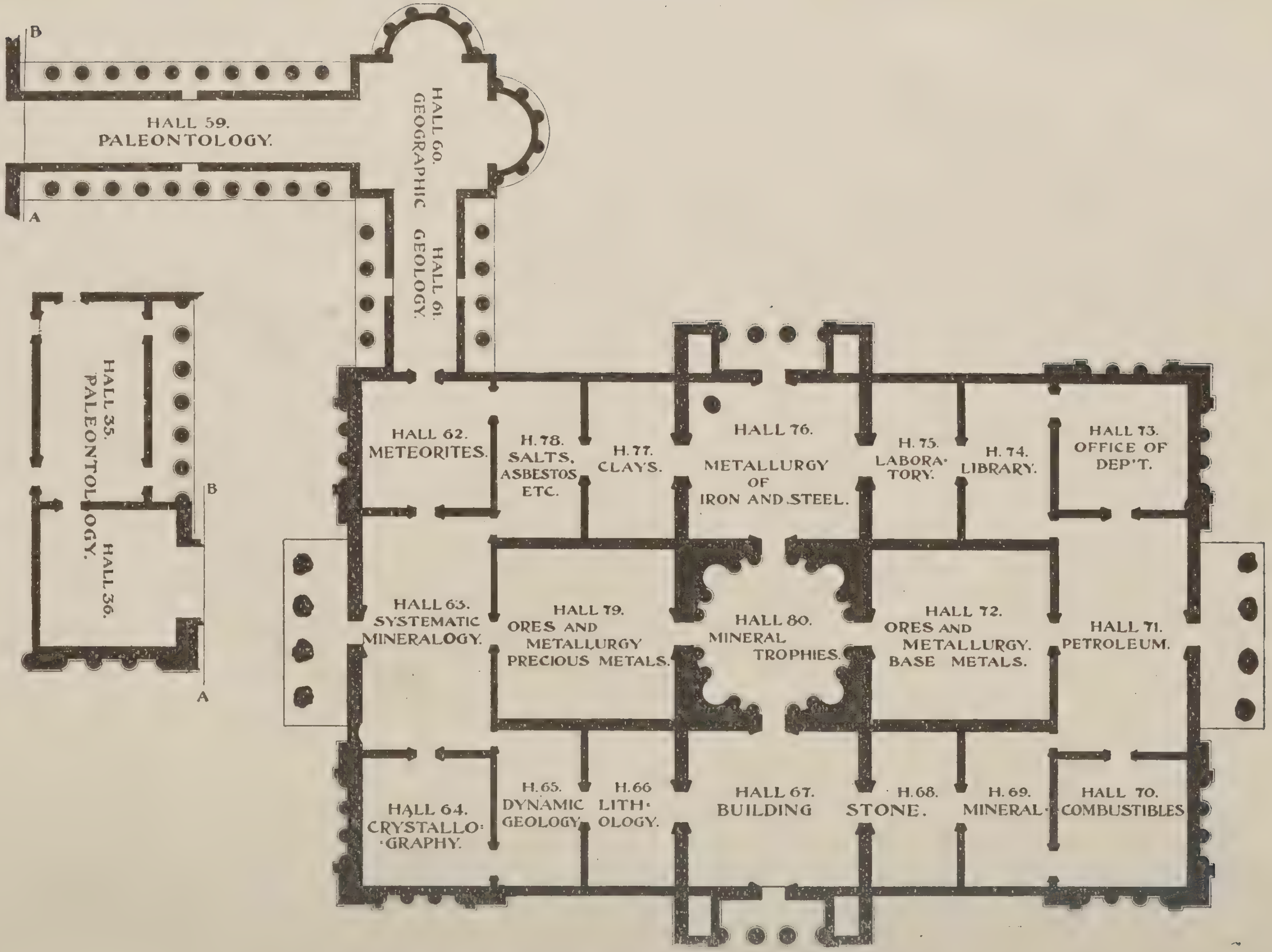
In the difficult matter of names of meteorites and the dates of their fall or find, the data given in Huntington's catalogue have, in the main, been accepted as correct.

No attempt at a plan of elaborate classification has been made, as none of the present systems seem to have gained sufficient acceptance to make them authoritative.

The divisions proposed by Maskelyne however, of *äerosiderites, äerosiderolites* and *äerolites* have been found to form so convenient a grouping that they have been followed throughout.

Grateful acknowledgments are due Dr. C. F. Millspaugh of this Museum for the generous aid he has given in preparing the photographs for the illustrations of the work, also to Prof. H. A. Newton and Dr. O. W. Huntington for information kindly furnished.

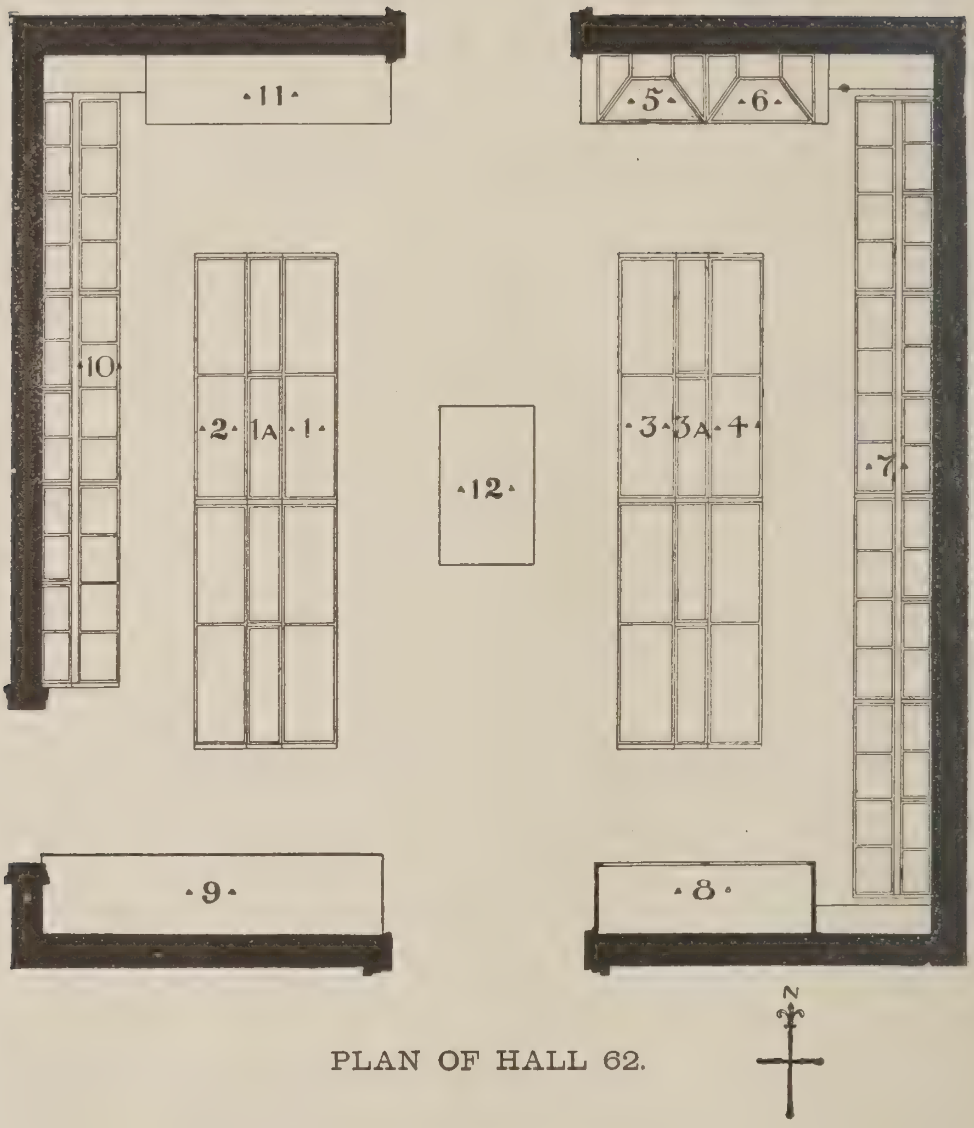
July 15, 1895. Oliver C. Farrington.



PLAN OF THE DEPARTMENT OF GEOLOGY.
Showing relation of Meteorite to other collections.

TABLE OF CONTENTS.

PAGE.
Arrangement of the Collection 7
Handbook of the Collection 9
Bibliography 31
Catalogue of the Collection 33
    Äerosiderites 35
    Äerosiderolites 45
    Äerolites 49
List of Casts of Meteorites 61
Index to Meteorites 62
General Index 66



PLAN OF HALL 62.

ARRANGEMENT OF THE COLLECTION.

The collection of meteorites occupies Hall 62 of the West Annex of the Museum. The number and disposition of the cases in the hall is shown by the accompanying plan. The smaller specimens are arranged in the chronological order of their fall or find, in Cases 1-4 inclusive.

They are grouped for convenience, as shown in the Catalogue, into the three classes of *äerosiderites*, (meteoric irons) *äerosiderolites*, (meteoric iron-stones) and *äerolites* (meteoric stones.) The äerosiderites occupy Cases 1 and 2, the äerosiderolites part of Case 3, and the äerolites, the remainder of Case 3 and Case 4.

The place of fall or find of each specimen, usually constituting the *name* of the meteorite, the date of fall or find and the weight of each specimen are shown by its label.

Cases 5 and 6 contain specimens weighing respectively 466 and 345 pounds, of the Kiowa County, Kansas, fall, together with smaller individuals and sections of others of the same fall. In Case 8 are placed a large mass and several hundred smaller fragments of the Phillips County, Kansas, meteorite, the aggregate weight of which is 1184½ pounds.

On the pedestal numbered 12, in the center of the hall, are supported two large masses weighing respectively 1013 and 265 pounds, of the Cañon Diablo, Arizona, meteorite. See Plate III, Fig. 3.

The total number of falls or finds represented by these specimens is 180 and their aggregate weight 4,720.6 pounds, (2,140.4 kilograms).

Cases 7 and 10 are devoted to casts which show the form and size of some of the more notable meteorites, together with specimens of pseudo-meteorites, of the Ovifak iron and of other terrestrial minerals which approximate in composition to those of meteoric origin.

Pedestals 9 and 11 bear full-sized models of the Chupaderos and San Gregorio, Mexico, meteorites, which illustrate the size of these, the largest known bodies of their class.

On the wall is a large map of North America showing the places at which meteorites have fallen or have been found in this country.

Nearly all of the specimens which now make up the collection have been obtained by purchase from Ward's Natural Science Establishment and Mr. Geo. F. Kunz. A section of the Seneca River meteorite has been kindly loaned for exhibition by Mr. G. Murray Guion of Chicago.

It is believed that the collection has already a size and value which entitle it to be considered one of the important ones of this country, if not of the world, and it is hoped that by gifts and exchanges its value may be so constantly increased as to maintain this position, and make it a profitable center for the study of meteorites.

HANDBOOK OF THE COLLECTION.

(In the following pages the figures in full-faced type refer to those on the specimen labels of the collection. From these, therefore, reference may be made to individual specimens of the collection, for the purpose of verifying or exemplifying the statements of the text.)

Meteorites are stony or metallic bodies of extra-terrestrial origin which fall to the earth from space.

They may fall at any time of the day or of the year and on any part of the earth's surface. Their fall is usually accompanied by luminous phenomena, such as the appearance of a ball of fire, showers of sparks and clouds of smoke and by sounds like those of cannonading, of thunder, or of bellowings and rattlings.

Observation of such falls is only occasional, since the larger number of meteorites fall into the sea or upon uninhabited regions. Daubrée calculates that the fall of a meteorite upon some portion of the earth's surface is a phenomenon of daily occurrence, yet the record of observed falls for the past century shows an average of only two and a half a year.

It is known, however, that such bodies have fallen to the earth since the very earliest periods of human history, because some of the most ancient records known to exist, refer to such phenomena.

Being regarded by ancient man and by barbarous tribes as of miraculous origin, they were often carefully preserved, enshrined and worshiped as gods, and thus a knowledge of their existence has come down to us.

Thus a stone which fell in Phrygia at a very early period was long worshiped as Cybele, "the mother of the gods" and about 204 B. C. was removed with great ceremony to Rome. It was described as "a black stone in the figure of a cone, circular below and ending in an apex above," so that it is very probable that it was a meteorite.

The Roman historian Livy tells of a shower of stones which took place on the Alban Mount about 652 B. C., by which the senate was so impressed that it held a solemn festival of nine days in honor of the event.

The famous Diana of the Ephesians and Venus of Cyprus were probably meteoric stones which were worshiped as gods.

The Moslems sacredly preserve at Mecca a stone whose history goes back beyond the seventh century, the descriptions of which leave little doubt that it was of extra-terrestrial origin.

The traveler Pallas found in 1772 a stone at Krasnojarsk (**159**) in Siberia, which was regarded by the Tartars as a "holy thing fallen from heaven." As it has well marked meteoric characters, their tradition regarding it was probably based upon observation of its fall.

A large mass of iron was found in Wichita County (**41**) Texas, a few years ago, which had been set up by the Indians as a kind of "fetich" or object of worship and revered by them as a body foreign to the earth and coming "from the Great Spirit." It was set up at a point where several trails met and was evidently visited periodically by them. This, too, was found upon examination to have the characters of a meteoric iron, so that it is probable that its fall had been witnessed by some member of the race at a previous period.

Ornaments made of meteoric iron have also been found upon the altars of mounds in Ohio, indicating that they may have been used as objects of worship by the Mound Builders.

The Chinese preserve many accounts of the fall of stones from the sky, the earliest recorded being about 644 B. C.

The oldest stone still preserved which is positively of meteoric origin is that of Ensisheim (**207**) Elsass, Germany. This fell November 16, 1492, between 11 and 12 A. M., making a hole about five feet deep in the ground. The stone weighed 260 pounds. King Maximilian being at Ensisheim at the time had it carried to the castle and after breaking off two pieces, one for the Duke Sigismund of Austria and the other for himself, forbade further damage and ordered it to be suspended in the parish church, where it is said it may still be seen hanging by a chain from the vault of the choir.

Although the fact of the fall of stones from the sky seemed thus so well established, the haze of superstition and exaggeration by which the accounts of such occurrences were surrounded was so great that scientific men were slow to believe in the possibility of such a phenomenon.

Moreover the advance of knowledge instead of furnishing additional reason for belief that bodies could reach the earth from the universe beyond, in fact made it seem very improbable. The courses of the heavenly bodies were found to be controlled by such immutable laws that any irregularity seemed impossible. The accounts of stones falling from heaven therefore were generally regarded by scientific men as the delusion of a few badly scared or very credulous observers.

As proof of this it may be noted that as late as 1772, three French Academicians, among whom was the renowned chemist Lavoisier, having investigated the stone which was said to have fallen at Lucè, France, in 1768, reported that in their opinion it was only an ordinary one struck by lightning.

In the next few years however, meteoric falls occurred under circumstances so accurately defined that their authenticity could not be denied.

On the 13th of December, 1795, at Wold Cottage (**215**) in Yorkshire, England, a stone weighing 56 pounds fell within ten yards of where a laborer was standing, penetrating 12 inches of soil and 6 inches of chalk rock. It was found when examined to be of different character from any ever before known in that region.

No phenomena of sound or light were observed by the laborer, but in the surrounding villages an explosion was heard like the firing of guns at sea and at some points a sound of something unusual passing through the air towards Wold Cottage.

Still more unmistakable was the fall which occurred at Krakhut (**216, 217**) near Benares, India, about 8 o'clock on the evening of December 19, 1798. A ball of fire appeared in a calm and cloudless sky, accompanied by a sound like that of thunder, and then the descent of a number of stones was observed by several Europeans and natives.

Finally at L'Aigle (**218, 220**) in the Department of Orne, France, about 1 P. M. April 26, 1803, occurred a shower of more than a thousand stones, the circumstances attending which were so unmistakable that even the skeptical French Academicians were obliged to give up their doubts. An exhaustive summary of the facts in regard to this fall having been made by the French physicist Biot, his conclusions led the whole scientific world to believe that from time to time, material bodies having an extra-terrestrial origin do come to the earth.

As a result of these conclusions such bodies, which are called *meteorites*, are now as far as possible carefully preserved and the phenomena attending their fall are accurately noted and recorded. The fact that they are the only material bodies which ever reach the earth from the universe beyond it, gives them a peculiar interest, and their study has taught something and may teach yet more of the nature of cosmic matter and forces.

While the meteorites of different falls vary in individual particulars, they all conform to a common type and possess as a whole characters which serve to distinguish them from any terrestrial bodies.

It is therefore possible when any body possessing these characters is found upon the earth, to assert with comparative certainty that it was of meteoric origin though its fall to the earth has not been observed. This is called a meteoric "find" in distinction from a meteoric "fall" and a large number of the meteorites now in collections have been obtained in this way.

This is especially true of the meteorites made up chiefly of iron, since their metallic character preserves them from decay and their weight and difference from ordinary stones make them noticeable to the ordinary observer. On account of the nickel-white color of their interior also, they are often taken by their discoverers for masses of silver and have been preserved for this reason. Of more than one hundred localities of these now represented in collections only nine metallic meteorites have actually been seen to fall.

The meteoric stones, on the other hand, unless their fall has been observed, are far less likely to be discovered, since they differ so little from ordinary stones in appearance that they are easily overlooked and under atmospheric influences quickly disintegrate and decay. Hence most of the stony meteorites now in collections have been seen to fall.

Over 530 distinct meteoric falls and finds are now known, of which the falls number about 270.

It has already been noted that but a small proportion of the meteorites which actually reach the earth are ever secured, since numbers of them fall into the sea or upon uninhabited regions. It will therefore be evident that any conclusions regarding the distribution of meteorites which may be drawn from maps showing where they have fallen must be imperfect and faulty. Such observations as have been made, however, indicate that meteorites are not attracted to any particular portion of the earth's surface and that the point at which they reach the earth is purely a matter of accident.

The times both of the year and of the day, at which meteorites fall, seem to be somewhat more regular.

A table compiled by Mr. R. P. Greg,* shows that more meteorites have fallen in June and July and less in December and January than in the other months.

A similar comparison of data by Haidinger,† regarding the times of day at which meteorites fall, shows that more have fallen in the afternoon than in the forenoon. This is a result, as shown by Professor H. A. Newton,‡ of their movement in direct rather than in retrograde orbits, i. e. of their *following* the earth.

---

*London Phil. Mag., November, 1854.

†Sitzungsb. d. k., Ak., d. Wissensch., Vienna, 1867.

‡Am. Jour. Sci., 3rd Ser , Vol. 36, p 1-14.

Among characters common to all meteorites which distinguish them from bodies of terrestrial origin may be noted, *first*, the varnish-like *crust* always found upon their surface. This is the result of heating and fusion of the surface during passage of the mass through the atmosphere. In the meteoric stones it is usually black and contrasts with the gray or brown of their interior (Winnebago Co., **340**, Knyahinya, **287**, Pultusk, **290**). Not infrequently, however, it is of the same color as the interior (Kesen, **258**, Washington Co., **345**, and Phillips Co., **350**). It is usually of a dull lustre (Pultusk, **291**, Mocs, **324**), but occasonally shining (Stannern, **226**, Knyahinya, **286**). In many individuals it differs in appearance on different portions of the stone, being smooth and compact on one part and on another, rough and slag-like.

Such appearances often indicate the position which the stone assumed during its fall, the portion bearing the smooth crust having been in advance (*die Brustseite*) while the other portion was at the rear (*die Rückenseite*), (Winnebago Co., **340**, Mocs, **331**). On meteorites which are largely metallic, the crust appears as a brown (Grand Rapids, **116**) or bluish (Estherville, **175**) oxidation of the surface, contrasting with the nickel-white color of the interior. It is never more than a millimeter in thickness (Forsyth, **241**, New Concord, **273**) and frequently exists only as a smoking of the surface (Winnebago, Co., **340**).

Other evidences of surface fusion are seen in the rounded metallic beads which stand out over the exterior of most stony meteorites. These are produced by metallic grains which offer a greater resistance to heat than the non-metallic portions of the stone. Where the metallic grains are quite small, they give the surface a papillated appearance (Trenzano, **268**, Bath, **351**) but larger grains produce larger protuberances (Washington Co., **347**).

Often there are visible on the crust of a meteorite (Stannern, **226**) lines of flow, which closely resemble, though on a much reduced scale, the features of a lava stream, and indicate that the surface of the meteorite was in a similar molten condition.

The rounding of the solid angles and sharp edges observable in most meteoric individuals (Winnebago Co., **340**), even metallic ones (Toluca, **12**, **21**), is likewise evidence of a former plastic condition of the exterior.

A *second* common characteristic of meteorites is to be found in the shallow *pits* which indent their surface. These vary much in size and depth, but usually have an appearance much like that of an impression made by a thumb upon a piece of soft clay or putty.

They are hence often called thumb marks (Phillips Co., **350**, Kesen **257**, Floyd Co., **154**). See Plate V, Fig. 1.

In the iron meteorites these are usually of greater size and depth and occasionally perforate the mass (Cañon Diablo, **146**). See Plate III, Fig. 3.

Similar pittings are observed upon partially burned grains of gunpowder picked up after the firing of the heavy guns at Woolwich, also upon the touch-holes of the cannon and upon masses of steel acted upon by an explosion of dynamite.

They are due in all these cases to the erosive action of gas revolving rapidly and moving spirally under high pressure, which bores into a solid mass with which it comes in contact as resistlessly as a gimlet.

This mechanical action is, moreover, accompanied by a chemical action resulting from the combustible nature of iron at high temperatures.

While at first thought it is difficult to realize how a medium so thin as air can offer resistance to the passage of a meteorite sufficient to fuse its surface, it can be better understood by bearing in mind the fact that air is a fluid made up of molecules as real as those of iron, and physically differing from them only in being more widely separated. A solid body, therefore, in moving through the air, compresses these particles, and by friction against them generates an amount of heat corresponding to its velocity. Experiments made by Joule and Thomson showed that a wire was warmed 1° C. by moving through air at a velocity of 175 feet per second, and that a velocity of 372 feet per second gave a rise in temperature of 5.3° C. Supposing, therefore, that the temperature would continue to increase as the square of the velocity, it can be calculated that a velocity of 20 miles per second, which is the average rate at which meteorites strike the atmosphere, would develop a temperature not far from 360,000°C., in a mass of the same character. We may therefore consider a meteorite in its contact with the atmosphere as exposed to a heat capable of melting it as readily as a piece of tallow is melted by being drawn across white hot iron, so that the wonder is, not that it is so easily fused, but that anything is left of it to reach the earth.

We are thus able also to understand the phenomena of light, of clouds, of smoke and of sounds like thunder or of an explosion, which usually accompany the fall of a meteorite.

The intense heat raises to incandescence the surface of the meteorite, causing it to glow with a light so powerful as occasionally to be visible at noon-day. The heated stratum of air agglomerates behind the advancing mass in the form of an igneous globe, making a flame shaped like that of a candle, and under the intense heat a large portion of the mass is dissipated into a vapor or smoke. The heat moreover, causes cracking of the surface (Linn Co., **255**, Dona Inez, **193**) and an unequal expansion of the mass which bursts it, often with explosive violence.

In spite of the high temperature to which its surface is raised, however, the substance of the meteorite is so poor a conductor that its interior is often scarcely heated at all. When picked up immediately after their fall, therefore, meteorites are often scarcely more than blood warm and in one remarkable instance, that of the Dhurmsala (**275**) meteorite, the fragments were so cold as to benumb the fingers of those who collected them. This is perhaps the only instance known in which the cold of space has become perceptible to human senses.

Another effect of the passage of a meteorite through the earth's atmosphere is to reduce very greatly its velocity, so that the speed of its fall when near the earth is comparable to that of an ordinary falling body. Hence instead of striking the earth at a velocity of from 10 to 45 miles a second, which is that at which meteorites enter the atmosphere, their force of impact may be very small. This is shown by the fact that several stones of the Hessle (**298**) fall, struck upon ice which was only a few inches thick and rebounded without either breaking the ice or being themselves shattered.

By dissipating, therefore, the smaller stones before they reach the earth and by reducing both the size and velocity of those which do come to it, the atmosphere protects us from what would otherwise be a dangerous bombardment, and makes the chances of injury to life or property from the fall of these bodies exceedingly small.

The *forms* of meteorites are very various and possess little regularity. Many are spheroidal (Pultusk, **290**), some oblong (Babb's Mill, cast, **383**), some tetrahedral (Mocs, **330**), some shell-like as if scaled from a spherical mass (Cañon Diablo, **373**) and many so irregular as to be lacking any definite form. They are as a rule as indefinite as to size and shape as the fragments from any block of stone when shattered with a hammer and it is therefore probable that they have been formed by the breaking up of a larger mass.

Such a disruption of a meteorite often takes place shortly before it reaches the earth, and as a result many individuals of a meteoric shower possess edges which are still rough and jagged and show little fusion of the surface (Winnebago Co., **340**). Perhaps the most remarkable instance of this is furnished by the stone of the Butsura (**398**) fall. At the time of fall of this meteorite three distinct reports were heard and five different fragments were picked up at four places several miles apart. Three of these fragments were found to fit together perfectly and at the points of contact to exhibit no crust, though their other surfaces were coated with it. The point of junction of the other two fragments could also be made out, though this surface possessed a crust hardly distinguishable from that of the rest of the mass. It was also found possible to unite all the fragments into one shell-like mass, showing that this was probably a unit as it entered the atmosphere and that the successive disruptions took place during its passage to the earth.

Similar variations in crust are observable among the individuals of nearly every meteoric shower, making it seem probable that they are produced by the breaking up of a single individual.

It should be noted, however, that some authorities prefer to regard the stones of a meteoric shower as members of a *swarm* of larger or smaller planetary individuals which had a previous independent existence.

In *size*, meteorites vary from complete individuals no larger than a pea (Winnebago Co., **340**) to the enormous mass of Chupaderos, Chihuahua, Mexico (Model **422**) whose weight has been variously estimated at from fifteen to twenty-five tons. The Phillips Co., Kansas, meteorite (**350**) if it reached the earth, as is highly probable, in a single mass, is the largest single äerolite in existence, the aggregate weight of the fragments so far found being 1300 pounds. The next largest is an individual of the Knyahinya, Hungary, fall, preserved in the Vienna Museum, having a weight of 647 pounds. Among the äerosiderites or iron meteorites, however, there are many of greater size and weight, as for example the Cranbourne (**68**) mass now preserved in the British Museum, which weighs about four tons, the Red River or Gibbs meteorite (**34**) in the Yale College Museum, weight 1630 pounds, and several Mexican meteorites.

The chemical study of meteorites has shown them to be made up of *elements* such as are common upon the earth and has as yet revealed none new to its constitution. About twenty-five have thus far been recognized, of which iron, silicon, magnesium, nickel, sulphur, phosphorus and carbon are the most important. The following list represents all that are known to occur:

Aluminium
Antimony
Arsenic
Calcium
Carbon
Chlorine
Chromium
Cobalt
Copper
Hydrogen
Iron
Lithium
Magnesium
Manganese
Nickel
*Nitrogen
Oxygen
Phosphorus
Potassium
Silicon
Sodium
Sulphur
Tin
Titanium

---

*Recent investigations by Prof. Ramsay have shown that what has been regarded as nitrogen, is largely made up of argon and helium. See Nature Vol. 52, p. 221.

These are usually present in combination, but hydrogen and nitrogen occur as occluded gases and carbon in the elementary form of graphite or diamond.

The following *compounds* occur, which in chemical composition and physical properties seem to be wholly similar to terrestrial minerals of the same name:

The silicates, chrysolite $(Mg, Fe)_2\ Si\ O_4$, enstatite, $Mg\ Si\ O_3$, bronzite, $(Mg, Fe)\ Si\ O_3$, diopside including diallage, $Ca\ Mg\ (Si\ O_3)_2 + Ca\ (Mg, Fe)\ (Si\ O_3)_2$, augite, $Ca\ (Mg, Fe)\ (Si\ O_3)_2 + (Mg, Fe)\ (Al, Fe)_2\ Si\ O_6$, labradorite, $(Na\ Al\ Si_3\ O_8 + Ca\ Al_2\ Si_2\ O_8)$ and anorthite, $Ca\ Al_2\ Si_2\ O_8$; the oxides, magnetite, $Fe\ O, Fe_2\ O_3$ and chromite, $Fe\ O, Cr_2\ O_3$; the sulphides, pyrite, $Fe\ S_2$, and pyrrhotite, $Fe_7\ S_8$, and the carbonate, breunnerite $Mg\ Co_3$ with $Fe\ O$.

Quartz, $(Si\ O_2)$, though so widely distributed upon the earth, is conspicuous by its absence from meteorites. Small crystals have, however, recently been observed in the crust of some of the Toluca irons,* and free silica occurs in several meteorites in the form of asmanite, a compound believed to be identical with tridymite. Zircon, $(Zr\ Si\ O_4)$ has also been found in one of the Toluca masses, and the presence of orthoclase, garnet and apatite in several meteorites is probable, though not proved. Several soluble salts, such as chloride of sodium, and sulphates of sodium, calcium and magnesium, have been found in meteorites, and the carbonaceous meteorites contain bituminous substances which closely resemble terrestrial bitumens. As occluded gases occur marsh gas and carbon monoxide and dioxide.

The soluble salts and breunnerite are regarded by Cohen as of secondary origin, i. e., formed after the entrance of the meteorite into the earth's atmosphere, and the same may be true of the gases and bituminous substances. Various other compounds found in meteorites have from time to time been described as distinct species but their identity with terrestrial minerals has later been established.

The following compounds found in meteorites are believed to have no representatives among terrestrial minerals:

Various alloys of nickel and iron, including taenite, $Fe_6\ Ni$, kamacite, $Fe_{14}\ Ni$, plessite, $Fe_{28}\ Ni_5$ and edmonsonite; chalypite, a compound of iron and carbon; cliftonite, a cubic form of graphitic carbon; cohenite, $(Fe, Ni, Co)_3C$; schreibersite, $(Fe, Ni)_3\ P$; troilite, $Fe\ S$; oldhamite, $Ca\ S$; osbornite, supposed to be a sulphide or oxysulphide of calcium and probably titanium; daubréelite, $Fe\ S, Cr_2\ S_3$, and lawrencite, $Fe\ Cl_2$.

The chemical character of these compounds indicates that the conditions under which they were formed differed from those which prevail upon the earth, in the absence of air or free oxygen and of water. The lack of the first is indicated by the phosphide of iron, schreibersite, which would, in the presence of oxygen, have been changed to a phosphate; also by the fact that the iron and nickel are in the elementary condition and not oxidized, as they are upon the earth's surface. The absence of water is proved by the fact that no hydrous minerals are present in meteorites.

---

*Groth's Zeitschr für Kryst. und Min., Bd. 24. p. 485.

It is known that either the atmosphere in which the meteorites were formed or one through which they at some time passed, contained a large amount of hydrogen, from the fact that it can be extracted in large quantities from some of the metallic meteorites. It was, too, under a much higher pressure than is that of the earth's atmosphere, since Graham obtained from the Lenarto meteorite 2.85 times its volume of mixed gases, of which hydrogen formed 85%. Under the pressure of the earth's atmosphere it is difficult to make iron absorb more than its own volume of this gas. The reducing action of this hydrogen-laden atmosphere must be very great and in general it may be said that meteorites differ from analogous terrestrial rocks in containing in a reduced state substances which occur as oxides upon the earth.

Considered as *mineral aggregates*, meteorites may be conveniently divided into three classes according as they are made up chiefly of iron, partly of iron and partly of stone or chiefly of stone.

The meteorites of the first class have been called by Maskelyne *äerosiderites* (from ἀὴρ, air, and οίδηρος, iron) or by Daubrée *holosiderites*, (ὅλος, whole, οίδηρος, iron). The term is frequently shortened to *siderite* but the abbreviation is objectionable on account of the liability of its confusion with the mineral of the same name. The meteorites of the second class are called by the same authors *äerosiderolites* (ἀὴρ, air, οίδηρος, iron, and λίθος, stone) or *syssiderites* (οὺν, with, οίδηρος, iron). Those of the third class are known as *äerolites* (ἀὴρ, air and λίθος, stone,) or by Daubrée are divided into the two groups of *sporado-siderites* (οποράς, scattered, οίδηρος, iron,) and *asiderites* (ἀ without, οίδὴρος, iron.)

The *äerosiderites*, as is indicated by their name, are made up chiefly of iron. This is, however, always alloyed with nickel. The percentage of iron in the mass varies between 87% and 97% and that of nickel from a fraction of one per cent to 15%.

Two exceptions to this are known among irons supposed to be meteoric. One is that of Octibbeha Co., Miss., which contains 38% of iron to 60% of nickel and the other that of Santa Catarina, Brazil (**97-108**) which bears 64% of iron to 34% of nickel. It is possible, however, that the latter is of terrestrial origin.

The association of iron and nickel in the form of an alloy was long thought to be a peculiarity of meteoric bodies, but at least two terrestrial minerals are now known, which are constituted of such an alloy. One of these, awaruite (**361**), contains 67% of nickel to 31% of iron, the other, josephinite (**367**), 60% of nickel to 23% of iron.

The iron found in large masses on Disco Island and other parts of West Greenland also resembles the äerosiderites very closely in composition, since it contains from 1 to 6% of nickel and small percentages of phosphorus and carbon.

These occurrences are so isolated, however, that in general, masses of iron alloyed with nickel, when found upon the earth's surface, may be regarded as being probably of meteoric origin, especially if they also exhibit a crust and pitted surface like that described, and etching figures such as will be mentioned later.

Other elements commonly occurring in the äerosiderites, though in much smaller quantities, are copper, cobalt, manganese, phosphorus, sulphur and carbon.

The phosphorus is usually combined with iron in the form of schreibersite, the sulphur with iron as troilite, while the carbon may be either free in a graphitic form or as minute diamonds, or combined with iron.

The proportions of the different elements as they commonly occur in the äerosiderites are illustrated by the following analyses of some of those represented in the collection:—

			Fe.	Ni.	Co.	Cu.	P.			
(1)	Toluca,...	(**7**)	90.72	8.49	0.44	....	0.18	X .63		=100.46
(2)	Braunau	(**55**)	91.88	5.52	0 53	2.07	....	C, S *tr.*		=100.
(3)	Bates Co., Mo......	(**95**)	89.12	10.02	0.26	0.01	0.12			= 99.53
(4)	Grand Rapids, Mich.	(**116**)	88.71	10.69	....	0 07	0.26	C.06	S.03	= 99.82
(5)	Glorieta Mt., N. M.	(**122**)	87.93	11.15	0.33	....	0.36			= 99.77
(6)	St. Croix Co., Wis..	(**125**)	89.78	7.65	1.33	*tr.*	0.51	C *tr.*	Sn *tr.*	= 99.27

The specific gravity of the meteoric irons ranges between 5.75 and 8.31, nearly all lying between 7.5 and 7.9.

Most meteoric irons present a distinct *crystalline structure*, the features of which are brought out by etching a polished surface with acids. There then appear upon the surface, bands or lines intersecting one another at various angles, according to the direction of the section. These are enclosed in a more or less unindividualized ground mass.

---

(1) Taylor, Am. J.Sc. Vol. 22 p. 374, 1856; (2) Duflos and Fischer, Pogg. Ann. Vol. 72, pp. 170, 475, 1847; (3) J. L. Smith, Am. J. Sc. 3rd series, Vol. 13, p. 213, 1877; (4) Riggs, ibid, Vol. 30, p. 312, 1885; (5) Mackintosh, ibid, Vol. 30, p. 238, 1885; (6) D. Fisher, ibid, Vol. 34, p. 381, 1887. For further analyses see Lithological Studies by M. E. Wadsworth, Mem. Mus. Comp. Zool., Harvard Coll., Vol. XI, Part I, Oct. 1884.

Upon close examination the bands are found to be made up of a broad, central plate depressed below the surface, which is bounded by narrow ones in relief. These are shown in Figs. 1 and 2, Plate II.

Analysis of these plates by Reichenbach has shown that the broader ones are made up of an alloy of nickel and iron containing a large percentage of iron and hence readily dissolved by the acid. This alloy he called *kamacite*. The narrow plates, made up of an alloy which he called *taenite*, contain a larger percentage of nickel, are less readily dissolved and hence stand out in relief. The ground mass, to which he gave the name of *plessite*, he considered as having a proportion of iron and nickel between the two. Recent investigations by Davison,* however, indicate that there may be but two alloys present, the plessite representing simply portions of the mass where the bands of taenite are so closely crowded as to protect the kamacite from the action of the acid. This is rendered more probable by observing the insensible gradations by which the finer lines, called by J. L. Smith Laphamite markings, pass into the ground mass as if there were no real division between them. See Plate II, Fig. 1.

The angles at which the bands meet are dependent, as has been stated, upon the direction of the section and also upon their parallelism to the faces of either the octahedron, cube or dodecahedron, of the isometric system. All of these planes may occur in one meteorite but commonly only those of one kind appear and give to the iron a characteristic structure, distinguishing them as either octahedral or cubic.

The varying thickness of the plates and differences in their angles of intersection produce a variety of figures which characterize irons of different falls. See Plates I, II and III. Since they were first described by Widmanstätten, they are called Widmanstätten figures. They form one of the most striking features of the metallic meteorites and were long thought to be peculiar to such bodies, but are now known to be imitated by the etching figures of steel and of the native iron of Greenland. They have been produced by Daubrée upon a mass artificially formed by fusing together iron, nickel and phosphides of iron and nickel. They are, therefore, rather to be considered as indicative of the conditions under which the meteoric mass originated than as representing any distinct property of extra-terrestrial matter.

As examples of coarse etching figures, *i. e.* those made up of broad bands, may be noted sections of the Toluca (**16**), Staunton (**79**), Robertson Co. (**83**) and Cañon Diablo (**147**), irons. More delicate figures, *i. e.* made up of narrower bands, can be seen in the Lion River (**62**), Smith's Mt., N.C. (**85**), Bear Creek (**89**), Bates Co., Mo. (**96**) and Hamilton Co., Texas (**131**), irons.

---

*Am. J. Sc 3rd ser , Vol. 42, p 64.

The finer lines were regarded by Neumann as indicating an essentially different structure from that shown by the Widmanstätten figures and they are hence often called Neumann lines.

As pointed out by Huntington,* however, every gradation can be traced between the coarsest Widmanstätten figures and finest Neumann lines, so that there is no reason for regarding them as distinct. In Huntington's view the coarser figures characterize the irons in which there was a large amount of foreign matter to be eliminated, the finer, the purer irons. The former moreover tend to an octahedral structure, the latter, a cubic.

Most authorities agree that the crystalline structure exhibited in the meteoric irons indicates that they remained for a long time in a fused or viscous state from which they cooled but slowly.

Thus Tschermak† states that "the greater number of meteoric irons exhibit a structure which indicates that each formed part of a large mass possessing similar crystalline characters and the formation of such large masses presupposes long intervals of time for tranquil crystallization at a uniform temperature". Sorby‡ also regards "the Widmanstätten figures as the result of such a complete separation of the constituents and perfect crystallization as can occur only when the process takes place slowly and gradually. They appear to me to show that the mass was kept for a long time at a heat just below the point of fusion."

Further evidence of this is seen in the curved or bent plates contained in some meteoric irons (Stutsman Co., **126**), which were probably formed as true planes but, remaining viscous longer than other portions of the mass, suffered subsequent distortion.

It should be noted that there are some irons usually regarded as meteoric, which exhibit no trace of the Widmanstätten figures (Chesterville, **56**, Allen Co., **92**, Maverick Co., **113**). Others show only a coarse, irregular network of markings (Seeläsgen, **375**, Puquois, **124**, Silver Crown, **130**).

These may be considered as having been formed under somewhat different conditions from those which prevailed in the formation of other meteoric irons, or it may be questioned whether they are not of terrestrial origin.

---

*Proc. Am. Acad. Arts and Sciences, May, 1886, also Am. J. Sc., 3rd ser., Vol. 32, p. 284.

†Sitz. Wien. Akad., 1875, Bd. 71, pp. 661-673.

‡Nature, 1877, Vol. 15, p. 498.

Other markings which may be noted upon the etched surfaces of many irons are produced by included nodules of troilite. These may take various forms, such as circular (Orange River, **72**, Allen Co., **91**), oval (Staunton, **80**), elongated (Toluca, **25**), radiated (Hamilton Co., **131**), or running in veins (Joe Wright Mountain, **121**).

Occasionally there appear upon the etched surfaces delicate, short, sunken lines running in parallel directions or intersecting at regular angles (Walker Co., **38**, Maverick Co., **113**; Hex River Mts., **115**). According to Brezina these mark also the position of inclusions of troilite.

Other scattered, irregular flakes of a bronze-like lustre, indicate the presence of schreibersite (Wichita Co., **41**, Careyfort, **50**, Youndegin, **118**).

Together with the crystalline structure many äerosiderites display well-marked cleavage, usually octahedral (Toluca, **17**, Henry Co., **136**, Kenton Co. **134**) but occasionally cubic (Braunau, **55**) or dodecahedral. This structure is also possessed by some irons which exhibit no etching figures whatever, and in general seems to be independent of the crystalline planes because the cleavage planes frequently pass through the crystalline plates, indicating that they are of separate origin.

The *äerosiderolites* consist usually of a spongy mass of nickeliferous iron in the pores of which are contained grains of silicates. The silicate most commonly found occurring in this way is chrysolite and its typical mode of occurrence is shown in the Krasnojarsk (**159**) meteorite. This meteorite, having been first reported by the traveler Pallas in 1776, is frequently known as the Pallas iron, and the name Pallasite is given to meteorites of this class. Those of Kiowa Co., (**200**) are excellent examples.

In the Rittersgrün meteorite, (**164**) the pores of the iron are filled with a mixture of asmanite and bronzite, in that of Atacama (**170**) with chrysolite mingled with pyroxene and chromite; in that of Estherville (**177**) with chrysolite, diallage, pyrrhotite and troilite. The äerosiderolites pass so gradually from the äerosiderites on the one hand to the äerolites on the other that their grouping as a distinct class is adopted only for convenience. Occasionally, too, in individuals of the same fall, both classes are represented. Thus some of the Kiowa Co. meteorites are true pallasites (**200, 202, 206**) while others are entirely metallic(**204,205**). Among the stones of the Estherville (**175**, **178**) fall, can be traced every gradation between äerosiderolites and äerolites.

Upon the metallic portions of the äerosiderolites the Widmanstätten figures can usually be brought out (Atacama **162**. Rockwood **184**) and, as these are quite similar to those of the wholly metallic meteorites, they indicate the existence of corresponding conditions in the formation of the mass.

Analyses of some of the äerosiderolites represented in the collection show the following composition:—

	(1) Atacama, Chile. (**160**)	(2) Krasnojarsk, Siberia. (**157**)	(3) Rittersgrün, Saxony, (**164**)	(4) Carroll Co., Ky. (**180**)	(5) Hainholz, Prussia. (**165**)
SiO_2	13.60	20.43	26.79	29.52	33.24
Fe	60.27	44.02	$Fe + Ni$ 50.41	20.48	4.12
Fe_2O_3					22.20
FeO	4.09	6.86	3.53	14.11	3.51
Al_2O_3	0.01	MnO 0.21	0.70		0.72
CaO			0.66		
MgO	15.68	23.67	6.31	31.37	30.52
Ni	5.73	5.37	Na_2O 0.48	4.22	1.05
Co		0.23		0.28	
Cu		0.03	0.02	P 0.02	$Cr_2O_3 + FeO$ 0.50
Sn			FeS 7.23		
H_2O					2.86
Insol	0.20	0.24			
	99.58	101.07	96.13	100.00	98.72
Sp. Gr.	6.16	5.44	4.29	4.41	4.61

From meteorites of this class every gradation can be traced to the *äerolites*, meteorites in which the stony or siliceous matter predominates. These usually contain scattered metallic grains, *sporadosiderites* of Daubrée (Kesen, **257**, New Concord, **274**, Homestead, **314**), but some show no metallic constituents whatever, *asiderites* of Daubrée (Alais, **221**, Juvinas, **237**). The äerolites are made up chiefly of the minerals chrysolite, bronzite, augite, enstatite or some other member of the pyroxene group, anorthite or other feldspar, chromite, nickel-iron and troilite. These are usually crystallized and occur in angular, splintery fragments, but are sometimes developed porphyritically in an amorphous or crypto-crystalline ground. The occurrence and association of these minerals is similar to that in the eruptive rocks of the earth, and these they closely resemble. Representatives of many of the different varieties of eruptive rocks can indeed be found among the äerolites, so that, in the view of Wadsworth, no distinctions in classification should be made between rocks of terrestrial and extra-terrestrial origin if they resemble one another in constitution. Thus the äerolites containing no feldspar and made up chiefly of chrysolite are classed by him with the peridotites, the different varieties finding representatives as follows:—Dunite, a rock made up chiefly of chrysolite and chromite, is represented by the meteorite of Chassigny; saxonite, composed of chrysolite and enstatite, by those of Homestead (**313**) Knyahinya (**284**) and Waconda (**389**); lherzolite, made up of chrysolite, enstatite and diallage, by those of Pultusk (**289**) and New Concord (**274**).

---

(1) Von Kobell and Rivero, Korrespondenz-Blatt Vereines Regensberg, 1851. Recalculated by M. E. Wadsworth on the supposition that the silicates constitute one-third of the mass.

(2) J. J. Berzelius, Ann. Phys. u. Chemie 1834, Vol. 33, pp. 123—135.

Recalculated by M. E. Wadsworth on the supposition that the silicates compose one-half of the mass.

(3) C. Winkler, Nova Acta Leop. Acad. Halle, 1878, Vol. 40, pp. 333, 282.

(4) J. B. Mackintosh, Am. J. Sc. 3rd ser, Vol. 33, p. 232. Mar. 1887. Recalculated by the author on the supposition that the silicates constitute three-fourths of the mass.

(5) C. Rammelsberg, Mon. Berlin Akad., 1870, pp. 322—325.

Other analyses may be found in the work of Wadsworth, previously cited.

Similarly the äerolites containing feldspar may be considered as corresponding to the basalts and gabbros in mineralogical constitution; basalt, made up of augite and anorthite, finding a representative in the stones of the Stannern (**225**) fall; gabbro, composed of anorthite and enstatite, in the meteorite of Juvinas (**237**).

While such a grouping is convenient for keeping in mind the mineral constitution of the different äerolites, it is doubtful whether its application should be pushed much farther, since the distinction of origin is one of considerable importance.

The classification suggested by Tschermak* for the äerolites is as follows:

I. Äerolites made up of chrysolite and bronzite with iron subordinate, texture mostly chondritic. (L'Aigle, Knyahinya, New Concord, Pultusk, etc.)

II. Äerolites made up chiefly of chrysolite or bronzite or other pyroxene.

(a) Chassignite, composed mostly of chrysolite. (Chassigny.)

(b) Amphoterite, composed of chrysolite and bronzite. (Manbhoom.)

(c) Diogenite, composed of bronzite or hypersthene. (Ibbenbuhren, Shalka.)

(d) Chladnite, composed of enstatite. (Bishopville).

(e) Bustite, composed of diopside and enstatite. (Busti).

III. Äerolites made up of augite, bronzite, and lime feldspar and having a shining crust.

(a) Howardite, composed of augite, bronzite and plagioclase, (Frankfort, Lontolaks.)

(b) Eukrite, composed of augite with anorthite or maskelynite. (Juvinas, Jonzac, Stannern, Peterborough.)

---

*Ber. Ak. Wien., Bd. 88, pp. 347, 371, 1883.

Following are analyses of some of the äerolites represented in the collection:—

	(1) Pultusk, Poland. **(289)**	(2) Iowa County, Iowa. **(312)**	(3) Schönenberg, Bavaria. **(254)**	(4) New Concord, Ohio. **(273)**
SiO_2	35.85	36.34	40.13	42.25
Al_2O_3	1.96	0.63	5.57	0.28
Fe	15.55	11.16	13.77	9.31
Fe_2O_3	3.85			
FeO	12.12	22.28	17.12	25.03
CaO	1.56		2.31	0.02
MgO	24.95	19.70	13.81	21.91
Na_2O	0.95	1.40	2.20	} 0.99
K_2O	0.39	tr.	0.73	
Cr_2O_3	2.21		0.60	
Ni		1.30	1.47	1.32
Co		0.08		0.04
Li_2O		tr.		
P			0.36	tr.
S			1.93	0.11
FeS		5.82		
	99.39	98.71	100.	101.26

	(5) Knyahinya, Hungary. **(284)**	(6) Stannern, Moravia. **(225)**	(7) Juvinas, France. **(237)**	(8) Bishopville, S. C. **(251)**
SiO_2	44.30	48.30	49.23	67.14
Al_2O_3	3.06	12.65	12.55	1.48
Fe			0.16	
Fe_2O_3			1.21	1.71
FeO	16.38	19.32	20.33	
CaO	2.73	11.27	10.23	1.82
MgO	22.16	6.87	6.44	27.12
MnO		0.81		*tr.*
Na_2O	1.00	0.62	0.63	
K_2O	0.66	0.23	0.12	
Cr_2O_3	0.80	$+FeO$ 0.54	0.24	
$Fe + Ni$	5.00			
P_2O_5			0.28	
S			0.09	
H_2O				0.67
FeS	2.22	tr.		
TiO_2			0.10	
	98.31	100.61	101.61	99.94

---

(1) C. Rammelsberg, Mon. Berlin Akad. 1870, pp. 448-452.
(2) J. L. Smith, Am. J. Sci. 1875, 3rd ser., vol. 10, pp. 362-363.
(3) C. W. Gümbel, Sitz. München Akad., 1878, vol 8, pp. 40-46.
(4) J. L. Smith, Am. J. Sci. 1861, 2nd ser., vol. 31, pp 87–98.
(5) E. H. von Baumhauer, Archives Néerland, 1872, vol. 7, pp. 146–153.
(6) C. Rammelsberg. Ann. Phys. u. Chem., 1851, vol. 83, pp. 591–593.
(7) C. Rammelsberg, Ann. Phys. u. Chem., 1848. vol. 77, pp. 585–590.
(8) W. S. von Waltershauser, Ann Chem. u. Phar., 1875, vol. 79, pp. 369-374.

In specific gravity the majority of äerolites range from 3.00 to 3.80, being on the whole heavier than terrestrial rocks of the same nature on account of the greater quantity of metallic constituents.

Viewed as to *structure* the greater number of äerolites are found to be made up chiefly of little spheres, varying in size from those as large as a cherry to those only visible under the microscope. These are called *chondri* from the Greek χονδρος, a ball, and meteorites possessing this structure are said to be *chondritic*.

The chondritic structure is often discernible by the naked eye, as may be seen in the specimens of Weston (**224**), Forsyth (**240**), Pusinsko (**250**), Trenzano (**268**), Knyahinya (**284**) and many others.

When examined with sufficient magnifying power the chondri can be seen to be composed of angular, crystalline fragments chiefly of chrysolite or some pyroxene. See Plate VI, Fig. 1. These may be present as one individual (monosomatic) or more commonly of several (polysomatic).

An eccentric fan-shaped chondrus made up of radiating fibres of enstatite is a very unique and characteristic form. One such may be noted in the section of the Simbirsk meteorite, shown in Plate VI, Fig. 1. Other arrangements of the grains or fibres which may be noted are concentric, reticulated and radiated.

The chondrus is frequently enclosed in a shell of metallic grains which gives it a distinct outline and separates it from the ground mass. This is illustrated in Plate VI, Fig. 2.

The conditions which have brought about the formation of these chondri are not well understood though the question has been much discussed and various hypotheses have been suggested. The views of earlier observers were to the effect that the chondri represented fragments of pre-existing rock which by oscillation and consequent attrition obtained a spherical form. Sorby* has regarded them as produced by cooling and aggregation of minute drops of melted stony matter. Tschermak† considers their origin similar to that of the spherules met with in volcanic tuffs, which owe their form to prolonged explosive activity in a volcanic throat, breaking up the older rocks and rounding the particles by constant attrition.

Different views are, however, set forth by Brezina‡ and Wadsworth§, who believe that the chondri have been produced by rapid and arrested crystallization in a molten mass.

---

*Geol. Mag. 1865 (1) ii, 447.

†Phil. Mag. 1876 (5) i, 497–507.

‡Die Meteoritensammlung in Wien, 1885, p. 19.

§Lithological Studies, p. 110.

The principal objection to the first view, pointed out by Wadsworth, is that fragments of pre-existing rock ought to show the constitution of the rock as a whole instead of a specialized structure. That to the second, pointed out by Merrill* in the case of the San Emigdio meteorite at least, is that the great variety of forms under which the minerals of a single stone often appear, make it impossible to conceive of them as crystallizing from a single magma.

It is evident that no positive answer can be given to the question as yet and it may be that the conditions under which the various structures have been produced have been essentially different.

The matrix or mass of the stone in which the chondri are imbedded is usually made up of consolidated mineral splinters such as might have been produced by the breaking down of the chondri themselves. It is occasionally, however, of a glassy or amorphous nature.

The structure of äerolites not chondritic is frequently brecciated (Weston, **223**, Taborg, **335**) i. e., made up of rock fragments cemented together, while others seem to have undergone metamorphism subsequent to their consolidation (Chantonnay, **232**).

Evidence of physical change subsequent to consolidation is given by the *slickensided* surfaces observable in many meteorites (Linn Co., **255**, Kesen, **267**, Bath, **351**).

These are smooth, polished surfaces seen in different portions of the mass and are analogous to those found along faults in terrestrial rocks. They indicate a slipping or gliding of one portion of the rock on another after it had become cooled and solidified.

In the Puquios meteorite, which has a mass wholly metallic, a distinct faulting was observed by Howell. As some of the Toluca irons were found to become extremely friable on heating, it is probable that this faulting might have taken place during the passage of the mass near the sun or some other hot body.

Veins are found penetrating the mass of many meteorites (Charsonville, **230**, Waconda, **310**, Mocs, **323**). These are frequently filled with metal (Schönenberg, **254**, Washington Co., **327**, a) and in this case may have been produced as suggested by Preston by flowing of the molten metal into fissures made by cracking of the mass during its passage through the air. Others, however, contain opaque, graphitic or amorphous substances which probably segregated previous to the entrance of the meteorite into the earth's atmosphere.

A class of meteorites in the formation of which igneous agencies could have played little part are those known as *carbonaceous*. These are black, very friable bodies having a specific gravity not over 2.00

---

*Proc. U. S. N. M. No. 11, 1888.

and containing carbon compounds closely resembling terrestrial bitumens. Notably in the Cold Bokkeveld meteorite (**246**) occurs a substance much like bitumen from which a wax-like hydrocarbon can be dissolved out by alcohol. Other examples of carbonaceous meteorites, are those of Alais (**221**), Orgueil (**282**), Entre Rios (**320**), and Kaba.

As these carbon compounds seem to exist only in the pores of the stone, it has been suggested by Maskelyne that they may have been absorbed during its passage through the atmosphere, but this is not certain. Besides the carbon compounds, some meteorites of this class contain soluble alkaline salts which act as a cement to consolidate the meteorite, but when moistened with water cause it to completely disintegrate. These salts are sulphates of sodium, calcium, magnesium and potassium.

Having thus traced in outline the principal characters of meteorites there remains for answer the interesting question as to what has been the probable origin of these bodies. While it is not the province of this Handbook to enter into any elaborate discussion of the question, a study of meteorites can hardly be considered complete without a mention of some of the different theories which have been proposed to account for their origin.

It is evident, as has been said, from the chemical character of the substances found in meteorites, that water and air must have been absent from the laboratory of nature in which they were formed.

It is apparently true also that life had nothing to do with the formation of the substances which meteorites contain. The constituent substances most likely to have been of organic origin are the hydro-carbons previously mentioned, which resemble terrestrial bitumens. The latter are generally regarded as being one of the products of the decomposition of vegetable matter, but that they may have had a mineral origin as well is not denied, so that the presence of similar substances in meteorites is no proof of previous life.

The close resemblance which äerolites bear to volcanic terrestrial rocks has led many to seek their origin in material ejected from the volcanoes of the earth or moon.

This view has had many able supporters, notably the astronomer Laplace and the mineralogist J. Lawrence Smith. A careful study however of the amount of projectile force required to throw the meteoric bodies beyond the attraction of the terrestrial or lunar sphere and of the amount of matter which must have been thus ejected in order to furnish the number of meteorites that have been observed, shows both to be far beyond any probable quantity.

It may also be urged against this view that the volcanoes of the moon are not now active and the chances are exceedingly few that matter thrown from them in times past, once missing the earth, would ever reach it again. Also that from terrestrial volcanoes no substances like those forming the metallic meteorites have ever been ejected, and that, while in general the äerolites resemble volcanic rocks, they are in fact so distinct as to be readily distinguished from them.

Another view which has been seriously urged is that meteorites have had a solar origin.

Such a hypothesis, however, requires that solid bodies, some of them combustible, should come from the hot sun, and further that their paths should be in a line parallel to the ecliptic. The latter is not the case with the paths of many meteorites.

By another hypothesis meteorites are regarded as having come from a shattered planet. It is evident from the facts just stated that such a planet could have had no atmosphere. The supposition however that it ever existed is purely an arbitrary one, as is also that of any internal force which could rend it in pieces. Moreover, from such a body we should expect fragments varying more in size than do those which have thus far come to us.

We must therefore look to some other source for the answer to our question. The preponderance of opinion at the present day seems to be that it may be found in those strange, erratic bodies, the comets.

We know that these are worlds without water, with a strange and variable envelope which takes the place of an atmosphere, worlds which travel repeatedly out into the cold of space and back to the sun and slowly go to pieces in the process. Such conditions correspond closely with those which we have already seen probably prevailed in the formation of meteorites.

Still stronger evidence of the cometic origin of meteorites is to be found in the similarity between the orbits of groups of meteors and those of certain comets. In 1866, Schiaparelli, having calculated the orbit and motion of the meteorites which produce the annual August star shower, found that they corresponded exactly with those of an observed comet. Later the orbit of Tempel's comet was found to accord with that of the meteors of the November star shower and other parallelisms were noted for smaller showers. More remarkable still is the evidence afforded by the history of Biela's comet. This comet, discovered in 1826 by Captain Biela, was found to have a period of revolution of 6.6 years and to regularly come into view at these intervals. It had previously been seen in 1772 and 1805 and returned to the solar system in due order in 1832. Being in an unfavorable position in 1839 it could not be seen, but at the time of its next appearance in 1846 it was found to have separated into two portions, which kept drifting farther apart during the time in which the comet remained visible. At its next appearance in 1852, the fragments were seen to be smaller and still more widely separated. In accordance with its times of revolution the comet should have reappeared in 1859, 1866, 1872, 1879 and 1885, but though carefully looked for, it has never been seen again.

On November 27, 1872, however, occured a meteoric shower extraordinary for the number and brilliancy of the meteors which flashed through the air. The orbit of these proved to be exactly that of Biela's comet. On the same date in 1885 occurred another remarkable shower of meteors, having the same orbit and radiant point as those of 1872. During this shower an iron meteorite weighing about 8 pounds fell at Mazapil in Mexico. The manifest conclusion, therefore, is that sometime between the years 1852 and 1872, Biela's comet was shattered in pieces and some of these meteors were the resulting fragments. These fragments being small, were mostly burned up in their passage through the upper part of the earth's atmosphere, but had they been larger, numbers of meteorites would probably have fallen to the earth.

The fact, however, that so few meteorites have fallen to the earth during the star showers has been urged by some authorities as proof that the meteors producing stones are of a different nature from those which we see only as shooting stars. Since however, every gradation may be traced from one to the other and astronomically they are all alike, there is little reason, in the view of many authorities, to doubt their similarity.

Attention has already been called to the fact that though upon the earth's surface iron is rarely found uncombined, there are masses found in the basalt of Greenland which are altogether metallic and which in composition and structure closely resemble the meteoric irons. Though other views as to their origin have been advanced, many facts point to the conclusion that these iron masses have been brought up with the basalt and therefore indicate the existence of metal of this character in the deep interior of the earth. It has long been known that the matter constituting the interior of the earth must be more dense than that of the rocks which form its crust, since the specific gravity of the earth as a whole is 5.5, while that of the rocks of the crust is not more than 2.7. Professor Dana has shown that if the interior were iron up to within 500 miles of the surface it would give to the earth its present density, and the outflow of iron at Greenland makes such a constitution seem very probable.

Since this material, too, so closely resembles the meteoric irons in constitution, and since basalts and peridotic rocks are found upon the earth which are analogous in constitution to many of the äerolites, it further seems probable, as pointed out by Daubrée, that the different meteorites represent in epitome the structure and constitution of the earth as a whole and that study of these is equivalent to penetrating by a side glance into the inaccessible depths of our own sphere.

Certainly, so far as present investigations have gone, a wonderful similarity in the constitution of the bodies of the universe is indicated, which may well lead to the belief that all knowledge gained regarding extra-terrestrial bodies but increases our sources of information concerning the history and structure of the earth itself.

BIBLIOGRAPHY.

For information in greater detail in regard to the subjects discussed in the foregoing pages, the reader will find the following works useful.

For lists of meteorites with localities and dates, see:

Catalogue of All Recorded Meteorites, with a Description of the Specimens in the Harvard College Collection. O. W. Huntington. Reprinted from Proc. Am. Acad. of Arts and Sci., 1887.

Die Meteoriten in Sammlungen, ihre Geschichte, mineralogische und chemische Beschaffenheit. Otto Buchner, Leipzig, 1863.

Die Meteoritensammlung des k. k. mineralogischen Hofkabinetes in Wien, am 1 Mai, 1885. Aristides Brezina, Vienna, 1885.

An Introduction to the Study of Meteorites, with a List of the Meteorites Represented in the Collection of the British Museum. L. Fletcher, London, 1890.

Guide dans la Collection de Météorites du Muséum d'Histoire Naturelle. Paris. Paris, 1889.

The Meteorite Collection in the U. S. National Museum. F. W. Clarke. From the Report of the Smithsonian Institution, 1885-86.

Catalogue of the Collection of Meteorites in the Peabody Museum of Yale College. E. S. Dana. American Journal of Science, Appendix to Vol. 32, 1886.

On the classification of meteorites, and the subject in general, see:

Beschreibung und Eintheiluug der Meteoriten, &c. G. Rose. Abhandlungen Ak., Berlin, Vol. 23, 1863.

Météorites. S. Meunier, Paris, 1884.

Lithological Studies. M. E. Wadsworth, Mem. Mus. Zool., Cambridge, 1884.

Die mikroskopische Beschaffenheit der Meteoriten. G. Tschermak, Stuttgart, 1883-85.

Meteoritenkunde. E. Cohen, Stuttgart, 1894.

On the chemical constitution of meteorites and their relations to terrestrial rocks, see:

Handbuch der Mineralchemie, pp. 901, 952. C. Rammelsberg, Berlin, 1860.

Die chemische Natur der Meteoriten. Same author. Abh. Ak., Berlin, 15, 1870 and 1, 1879.

Études Synthétiqnes de Géologie Expérimentale. A. Daubrée, Paris, 1879.

Cours de Géologie Comparée. S. Meunier, Paris, 1874.

Original Researches in Mineralogy and Chemistry by J. Lawrence Smith. Edited by J. B. Marvin, Louisville, Ky., 1884.

Article on "*Iron,*" *System of Mineralogy.* E. S. Dana, New York, 1893.

For the astronomical relations of meteorites, their spectra, origin, etc., see papers by J. Norman Lockyer in Nature 1888, vol. 37, pp. 55, 80; by H. A. Newton in Nature, 1879, vol. 19, p. 315, Proc. Am. Assoc. Adv. Sci. Vol. 35. 1886, Am. Jour. of Sci., Feb. and June 1886, and July 1888; and by R. S. Ball, Nature 1879, vol. 19, p. 493.

Descriptions of most American meteorites published soon after their fall or find are contained in the volumes of the American Journal of Science.

CATALOGUE OF THE COLLECTION.

EXPLANATORY.

The following abbreviations are used in this Catalogue.

W. f.,	Widmanstätten figures.
W.,	Purchased of Ward's Natural Science Establishment.
K.,	Purchased of Geo. F. Kunz.
*	Specimens available for exchange.
Cat. No.,	Numbers under this heading refer to those marked upon Museum labels.

CATALOGUE OF THE COLLECTION.

ÄEROSIDERITES OR IRON METEORITES.

Cat. No.	Date of Fall or Find.	NAME AND DESCRIPTION.	Weight in grams†
	Fell 1400 ? Recognized 1811.	**Elbogen,** Bohemia.	
1		Etched fragment showing W. f. (W.)	2.5
	Found 1780.	**Descubridora, Catorce,** San Luis Potosi, Mexico.	
2		Polished and etched slab. W. f. in long parallel bands crossed at intervals by others nearly at right angles. (W.)	35
	Found 1784.	**Bembdego, Bahia,** Brazil.	
3		Scalings from crust, showing magnetite. (W.)	
4		*Irregular fragment, one surface polished. Octahedral cleavage well exhibited. (W.)	32
5		Large slab showing natural and etched surfaces. The etched surface exhibits a coarsely crystalline structure with imperfect W. f.	1,132
6		Etched slab showing imperfect W. f., elongated nodules of troilite and a group of schreibersite inclusions. (W.)	855
	Found 1784.	**Xiquipilco, Toluca,** Mexico.	
7		*Complete individual. Form spheroidal. (W.)	464.5
8		*Complete individual. Irregular form. Octahedral cleavage well exhibited. (W.)	99.5
9		*Complete individual. Spheroidal form. Surface apparently water-worn. (W.)	263.5
10		Complete individual. Apparently water-worn surface. (W.)	251
11		*Complete individual. Spheroidal form. (W.)	227
12		Spheroidal individual with one etched face showing the typical, coarse W. f. and nodules of troilite. (W.)	816
13		Complete individual showing distinct octahedral cleavage. (W.)	112.5
14		*Polished slab. (W.)	225.5
15		Crescent shaped mass with surface 20x40 cm. etched. Shows coarse W. f. and nodules of troilite of various shapes and sizes. (W.)	16,665
16		Similar to above specimen but smaller. (W.)	6,166
17		Broken fragment showing well developed cleavage planes. (W.)	1,997
20		*Complete individual. (W.)	1,880
21		Complete individual, spheroidal. Surface very smooth. (W.)	1,107
22		Complete individual, hemispheroidal. Cleavage planes well marked. (W.)	28,038
23		Complete individual. Hemispheroidal. Shallow pits appear on the surface, (W.)	46,040

---

† 1 gram equals 15½ grains; 1000 grams equal 2.205 pounds.

ÄEROSIDERITES OR IRON METEORITES.

Cat. No.	Date of Fall or Find	NAME AND DESCRIPTION.	Weight in grams.
	Found 1784.	**Xiquipilco, Toluca,** Mexico.	
24		Complete individual, spheroidal. Surface smooth and pitted. (W.)	18,025
25		Thin slab, etched. The W. f. are very distinct and regular. Nodules of troilite of various shapes are included. See Plate I, Fig. 1. (W.)	1,900
26		Like previous specimen, but W. f. less distinct. (W.)	2,423
27		Complete individual, crescentic in form. Shows strong tendency to scaling and decomposition. Drops of lawrencite appear on the surface. (W.)	19,954
370		*Section of flattened individual with etched surface. The latter shows coarse, well marked W. f. and several irregular nodules of troilite. Natural surface deeply pitted. (W.)	4,535
371		*Full-sized slab, etched. Shows the usual W. f. and coarse, vein-like masses of troilite. (W.)	792
372		*Complete individual showing pittings and natural surface. Form pyramidal. (W.)	2,506
	Found 1784.	**Ixtlhuaca, Toluca,** Mexico.	
18		Complete individual. Surface pitted and covered with crust. (K.)	3.000
19		Scalings from previous specimen. (K.)	60
	Found 1792.	**Zacatecas,** Mexico.	
28		Thin fragment, etched. No W. f. (W.)	5.7
	Found 1793.	**Cape of Good Hope,** Africa.	
29		Polished slab of brilliant nickel-white color. (W.)	27
	Found 1802.	**Albacher Mühle, Bitburg,** Rhenish Prussia.	
30		Polished slab. Shows large pores and slag-like surface, due to its having been passed through a furnace. (W.)	70
31		*Fragment, three sides polished. The natural surface appears to be altering to limonite. (W.)	72
	Known 1804.	**Misteca, Oaxaca,** Mexico.	
32		Porous slab, etched. W. f. quite distinct. (W.)	86
	Known 1804.	**Charcas, San Luis Potosi,** Mexico.	
33		Thin slab, etched. Well marked W. f. (W.)	62
	Found 1808.	**Cross Timbers, Red River,** Texas.	
34		Chiseled fragment, one end etched. W. f. well brought out. (W.)	55
	Found 1814.	**Lenarto,** Saros, Hungary.	
35		Square slab showing crust on one side and one etched surface. No W. f. (W.)	47
	Found before 1819.	**Burlington, Otsego Co.,** New York.	
36		Triangular slab, etched on one surface. Very delicate W. f. (W.)	32

ÄEROSIDERITES OR IRON METEORITES.

Cat No	Date of Fall or Find.	NAME AND DESCRIPTION.	Weight in grams.
	Known 1827.	**Sancha Estate, Santa Rosa, Coahuila,** Mexico.	
37		Thin, polished slab, a portion etched, but no W.f. brought out. (W.)	70
90		Turnings. (K.)	10
	Found 1832.	**Walker County,** Alabama.	
38		Thin, polished slab. The etched surface bears intersecting short straight lines similar to those regarded by Brezina in the Hex River Mountains iron, as plates of troilite. (W.)	25.5
39		Worked mass. (W.)	128
	Fell Aug. 1, 1835.	**Charlotte, Dickson Co.,** Tennessee.	
40		Thin slab, one surface etched. Typical W. f. (W.)	7
	Known 1836.	**Wichita County,** Texas.	
41		Full-sized slab, etched. Shows coarse W.f., nodules of troilite and scattered flakes of schreibersite. (W.)	1,396
	Found 1837.	**Butcher Irons, Desert of Mapimi, Coahuila,** Mexico.	
42		Large, thin slab, a portion etched. The latter shows a stippled surface intersected by numerous short, straight lines, probably of troilite, also nodules of same. (W.)	2,140
43		Large segment showing natural, polished and etched surfaces. Natural surface very smooth. Etched surface like that of previous specimen. (W.)	3,402
	Found 1839.	**Putnam County,** Georgia.	
44		Cleavage pieces showing octahedral form, separated by thin plates of taenite. (K.)	
	Found 1840.	**Magura, Arva,** Hungary.	
45		Etched slab showing delicate but very distinct W.f. The plates intersect at angles of 109°. (W.)	6
46		*Irregular fragment. Cleavage structure prominent. (W.)	137
47		Fragment showing natural and etched surface. No W. f. (W.)	166.5
	Described 1840.	**Cosby's Creek, Cocke Co.,** Tennessee.	
48		*Several irregular fragments, all showing octahedral cleavage. (W.)	40
49		Irregular fragment, cleavage structure prominent. The tin-white plates are taenite. (W.)	42.5
	Found 1840.	**Careyfort, De Kalb Co.,** Tennessee.	
50		Thin slab, one surface etched but showing no W. f. Troilite nodules and flakes of schreibersite appear on the etched portion. (W.)	55

ÄEROSIDERITES OR IRON METEORITES.

Cat. No.	Date of Fall or Find.	NAME AND DESCRIPTION.	Weight in grams
	Found 1840.	**Coney Fork, Carthage, Smith Co.,** Tennessee.	
51		Rectangular slab, polished. (W.)	50
52		Thick slab showing natural, polished and etched surfaces. Coarse W. f. are dimly outlined on the latter. The lines of taenite are very delicate. (W.)	78
	Found 1845.	**Sevier County,** Tennessee (Identical with Cocke Co.)	
53		*Five fragments of about 20 grams each, cleaving in octahedrons, which are separated by bright plates of taenite. (W.)	114
	Fell 1846.	**Deep Springs Farm, Rockingham Co.,** North Carolina.	
87		Thin slice showing sawed and etched surfaces. No W. f. (W.)	7
	Fell 1847.	**Braunau, Hauptmannsdorf,** Bohemia.	
55	July 14, 3:45 A. M.	Sawed block showing natural surface with pits. The lustre of the natural surface is like that of blued steel. (K.)	47
54		*Block showing polished and torn surface. (W.)	8.5
	Found 1847.	**Chesterville, Chester Co.,** South Carolina.	
56		Thin slab, etched. The etching brings out a network of irregular lines on the surface but shows no W. f. (W.)	6
	Found 1847.	**Seeläsgen,** Brandenburg, Prussia.	
57		Chiseled fragment. No cleavage structure visible. (W.)	41.5
375		Etched slab, containing large nodule of troilite. The iron is seen to be made up of large irregular plates but no W. f. appear. (W.)	12.5
	Found 1847.	**Murfreesboro, Rutherford Co.,** Tennessee.	
58		Etched slab showing distinct W. f., the plates of which run principally at right angles. (W.)	20.5
	Found 1850.	**Seneca Falls, Seneca River,** New York.	
60		Sawed section showing natural surface and fracture. Octahedral cleavage very distinct. One surface partially etched, bears an initial of the name of the first owner, Mr. L. C. Partridge. Loaned by G. Murray Guion.	300
	Known 1853.	**Lion River,** Great Namaqualand, South Africa.	
61		Sawed slab, one surface polished. (K.)	49.5
62		Etched slab, with crust. Beautiful W. f. are displayed, the plates being narrow and very distinct. See Plate III, Fig. 2. (W.)	62.5
376		*Like No. 62, but W. f. less distinct. (W.)	44
	Found 1853.	**Union County,** Georgia.	
63		Cleavage fragments with surface considerably oxidized. (W.)	1.5

ÄEROSIDERITES OR IRON METEORITES.

Cat No.	Date of Fall or Find.	NAME AND DESCRIPTION.	Weight in grams.
	Found 1853.	**Knoxville, Tazewell Co.,** Tennessee.	
64		Slab showing natural and polished surface. (W.)	17
	Found 1854.	**Madoc, Hastings Co,,** Ontario, Canada.	
65		Spheroidal fragment showing natural surface with pittings. (W.)	9
66		Thin, sawed slab with natural surface. (K.)	5
	Found 1854.	**Emmitsburg, Frederick Co.,** Maryland.	
67		Etched slab with natural surface. W. f. well brought out. (W.)	28.5
	Found 1854.	**Cranbourne,** Melbourne, Victoria, Australia.	
68		Irregular fragment much decomposed. A portion altered to limonite. Silvery plates of taenite are numerous through the mass. (W.)	34.2
69		Cleaved fragment, octahedral structure prominent. (W.)	4.5
	Found 1854.	**Yarra Yarra River,** Victoria, Australia. (Probably identical with **Cranbourne.**)	
70		Thin slab showing natural and etched surface. Crystalline structure is indicated on the etched surface, but no distinct W.f. are shown. (W.)	15
	Known 1856.	**Orange River,** Garib, South Africa..	
71		Sawed section with natural surface, smooth and deeply pitted. (K.)	114
72		Etched slab showing typical W. f. and nodule of troilite. (W.)	95 5
	Found 1856.	**Nelson County,** Kentucky.	
73		Apparently a large scaling slightly oxidized. (W.)	23
	Known 1856.	**Denton County,** Texas.	
74		Thin, sawed fragment. Along an old fracture are numerous parallel grooves which are probably lines of decomposition. (W.)	3
	Found 1857.	**Laurens County,** South Carolina.	
76		Thin slab, etched, showing beautiful W. f. The delicate bands, silvery white in color, and intersecting in equilateral triangles, stand out in sharp contrast to the dull gray of the ground mass. See Plate III, Fig 1. (W.)	13
	Found 1858.	**Staunton, Augusta Co.,** Virginia.	
78		Full-sized slab, polished and etched. Shows typical W. f. and large nodule of troilite. (W.)	1,595
79		Slab with crust, etched. The crystalline plates have an ovoid form and intersect very irregularly. (W.)	665
80		*Slab with crust, polished and etched on two surfaces. Beautiful, broad and distinct W. f. (W.)	100.5

ÄEROSIDERITES OR IRON METEORITES.

Cat No.	Date of Fall or Find.	NAME AND DESCRIPTION.	Weight in grams
	Found 1858.	**Trenton, Washington Co.,** Wisconsin.	
81		Thin slab, etched, showing typical W. f., the plates of which intersect at angles of 35°. (W.)	137
82		*Specimen similar to foregoing, but smaller. (W.)	46
	Known 1860.	**Coopertown, Robertson Co.,** Tennessee.	
83		Thin slab, etched. The W. f. are made up of broad plates, 5mm. in thickness. (W.)	82.5
	Found 1860.	**Lagrange, Oldham Co.,** Kentucky.	
84		Sawed section with crust and etched surface. W.f. only slightly indicated. (W.)	47
	Recognized 1866.	**Smith's Mountain, Rockingham Co.,** North Carolina.	
85		Thin slab with crust, etched. Well marked W. f. Some of the bands are of oval shape. (W.)	17
86		*Similar to previous specimen. (W.)	13
	Found 1866.	**Bear Creek, Denver Co.,** Colorado.	
88		Fragment showing crust, Octahedral cleavage well displayed. (W.)	43.5
89		Thin slab, etched. Well marked W. f., the plates of taenite being very distinct. (W.)	27
	Found 1866.	**Juncal,** Paypote, Chile.	
140		Thin slab with crust, etched. Shows well marked W. f., the plates of taenite being very distinct. (W.)	60
	Found 1867.	**Allen County,** (near **Scottsville**) Kentucky.	
91		Full-sized slab, etched. Contains a circular nodule of troilite. The etched surface has the appearance of a network of delicate, straight lines overlaying a granular base. (W.)	364
	Found 1867,	**Auburn, Macon Co.,** Alabama.	
92		Sawed fragment showing crust on all surfaces but one. (W.)	5
	Found 1873.	**Chulafinnee, Cleburne Co.,** Alabama.	
94		Thin slab, etched. Broad W. f, are dimly outlined. (W.)	29
	Found 1874.	**Butler, Bates Co.,** Missouri.	
95		Etched slab. W. f very distinct. The plates of the latter seen with a lens appear to be made up of a number of smaller ones, which anastomose. There are also comb-like markings, made up of innumerable fine lines. (K.)	75.5
96		Same as previous specimen but containing nodule of troilite. (W.)	71.5
	Known 1875.	**Santa Catarina,** Ric San Francisco do Sul, Brazil.	
97		*Spheroidal mass, having the well known limonite yellow color of the Santa Catarina irons. More or less honey-combed by decay. (W.)	217

ÄEROSIDERITES OR IRON METEORITES.

Cat. No.	Date of Fall or Find	NAME AND DESCRIPTION.	Weight in grams
	Known 1875.	**Santa Catarina,** Rio San Francisco do Sul, Brazil,	
99		Similar to previous specimen, except that one surface is polished, showing a compact, metallic interior. (W.)	921
100		Similar to No. 97. (W.)	2,579
103		Similar to No. 97. (W.)	4,252
98		Mass only slightly altered, of iron black color and metallic lustre. (K.)	261
101		*A number of fragments of various sizes, apparently altered to limonite, but, according to Derby, portions of a porphyritic crust. (K.)	1,814
102		*Similar to No. 97. (K.)	766
104		“ “ “ (K.)	3,344
105		“ “ “ (K.)	10,884
106		“ “ “ (K.)	11,576
107		* “ “ “ (K.)	3,174
108		* “ “ “ (K.)	1,577
	Found 1876.	**Cleveland, Green Co.,** Tennessee.	
109		Polished slab, etched. No W. f. brought out by etching. (K.)	100
	Found 1877.	**Dalton, Whitfield Co.,** Georgia.	
110		Thin, etched slab showing coarse, typical W. f. and crust. (W.)	81
	Found 1880.	**Lexington County,** South Carolina.	
111		Thin slab, etched. Etching divides the surface into irregular grains, but no regular structure is visible. (W.)	23.5
	Found 1880.	**Ivanpah, San Bernardino Co.,** California.	
112		Chiseled fragment. No evidence of cleavage. (W.)	3
	Found 1882.	**Maverick County,** (Fort Duncan) Texas.	
113		Thin slab with reddish crust, etched. The etched surface has a stippled appearance, and shows a network of short, straight lines, probably representing plates of troilite. Small grains of troilite are also present. (W.)	104
	Found 1882.	**Jenny's Creek, Wayne Co.,** West Virginia.	
114		*Three chiseled fragments showing cleavage octahedrons, separated by bright plates of taenite. (K.)	16.5
	Found 1882.	**Hex River Mountains,** Cape Colony, So. Africa.	
115		Sawed slab, one surface etched. Neumann lines are partially discernible, but more prominent are the parallel systems of troilite plates described by Brezina. These are beautifully shown in this specimen. (W.)	448
	Found 1883.	**Grand Rapids,** Michigan.	
116		Full-sized slab, polished and etched. Shows very distinct and striking W. f. made up of thin plates packed together in bundles. (W.)	1,160.5

ÄEROSIDERITES OR IRON METEORITES.

Cat. No.	Date of Fall or Find	NAME AND DESCRIPTION.	Weight in grams.
117	Found 1883.	**Grand Rapids,** Michigan. Full-sized, thick section, polished and showing W. f. like previous specimen. (W.)	7,881
118	Found 1884.	**Youndegin,** Western Australia. Full-sized, elongated slab, showing pittings, crust, polished and etched surface. The W. f. are very coarse, many of the plates being 1.5-2 cm. in thickness. They are also crossed by a series of finer lines nearly at right angles. Troilite and schreibersite are present. (W.)	1,087
119		*Polished fragment with crust. (W)	20.5
120	Found 1884,	**Joe Wright Mountain, Independence Co.,** Arkansas. Thin slab, etched, showing nodules of troilite and typical W. f. The arrangement of plates about one of the troilite nodules suggests a spherulite. (W.)	98.5
121		Etched slab, showing markings like previous specimen except that the troilite occurs in interlocking veins. (K.)	33
122	Found 1884.	**Glorieta Mountain, Santa Fe Co.,** New Mexico. Thin lab with crust, polished and etched. The well known W.f. of this iron are fully displayed. (W.)	1,271
123		Square slab, etched, showing both coarse and fine W. f. (K.)	152
124	Found 1884.	**Hammond, St. Croix Co.,** Wisconsin. Thin slab, showing one etched and one polished surface. The W. f. have a peculiar, shagreened appearence, due to their grouping in smaller and larger squares and to scattered flakes of schreibersite. (W.)	35
125		Like previous specimen except that the W. f. are more distinct and the crust attains in some places a thickness of 1 mm. (W.)	20
377	Found 1885.	**Puquios,** Chile. Full-sized slab, etched. Irregular W. f. are dimly brought out by the etching, also flakes of schreibersite. (W.)	154
126	Found 1885.	**Stutsman County,** North Dakota. Thin fragment, one surface etched. W. f. are but dimly outlined. Many of the plates appear bent. (W.)	7
127	Described 1885.	The **Lea Iron,** Tennessee. Large thin slab, showing crust, polished and etched surfaces. Typical W. f, (W.)	234
128	Described 1886.	**Thunda,** Windorah, Queensland, Australia. Sawed slab, one surface etched. W. f. distinct and regular. (W.)	154

ÄEROSIDERITES OR IRON METEORITES.

Cat No.	Date of Fall or Find.	NAME AND DESCRIPTION.	Weight in grams.
129	Found 1887.	**Chattooga County,** (Holland Store) Georgia. Thin fragment with crust. Polished surface. (W.)	28
130	Found 1887.	**Silver Crown, Laramie Co.,** Wyoming. Etched slab with crust. Structure coarsely crystalline, with a few rectilinear figures. Lines of taenite very distinct. (W.)	71
154	Found 1887.	**Floyd County,** (Indian Valley Township,) Virginia. Nearly complete individual, with natural surface. Crust yellowish-brown. Pittings broad and shallow. (K.)	13,142
378		Scalings from previous specimen, also highly polished fragment. (K.)	
131	Found 1888.	**Hamilton County,** Texas. Full-sized, thin slab, showing polished and etched surfaces. The W. f. appear as beautifully distinct and delicate lines running parallel in two directions throughout the mass. Troilite is distributed in radiating veins. See Plate I, Fig 2, and Plate II. (W.)	3,406
132	Found 1888.	**Welland,** Ontario, Canada. Segment, showing etched and natural surfaces. W. f. distinct and regular. Scattered grains of troilite are present. A marked tendency to octahedral cleavage is apparent. (W.)	715.5
133	Found 1889.	**Kenton County,** Kentucky. About one-third of the original mass, showing crust and polished surface. Contains nodules of troilite. (W.)	36,600
134		Full-sized slab, etched. W. f. very distinct and regular. Shows marked cleavage and tendency to separate along the cleavage planes. Very perfect octahedrons can be cleaved out from the mass. (W.)	9,312
135		*Full-sized slab. Both sides polished. (W.)	12,231
136	Found 1889.	**Henry County,** Virginia. Cleavage pieces, (octahedral) much oxidized. (K.)	79.5
137	Found 1890.	**Bridgewater, Burke Co.,** North Carolina. Thin slab with natural and etched surfaces. Exhibits well marked W. f. (W.)	19
138	Found 1890.	**Kendall County,** Texas. Thin slab with natural, sawed and etched surfaces. The etched surface exhibits a coarsely granular structure, crossed by a network of delicate, straight lines. Shows numerous nodules of troilite. (W.)	118
139	Found 1890.	**Nagy-Vazsony,** Hungary. Thin slab showing natural, etched and polished surfaces. Typical W. f. (W.)	37

ÄEROSIDERITES OR IRON METEORITES.

Cat. No.	Date of Fall or Find.	NAME AND DESCRIPTION.	Weight in grams.
	Described 1890.	**Ellenboro, Rutherford Co.,** North Carolina.	
153		Spheroidal mass showing natural and etched surfaces and fracture. The latter shows the iron to be highly crystalline, and to possess octahedral cleavage. (W.)	1,506
	Found 1891.	**Cañon Diablo,** Arizona.	
141		*Three complete individuals apparently scaled off from a larger mass. All show the smooth surface and characteristic pits of this iron. (W.)	844
142		*Complete individual, ovoid in form. Crust and pits like No. 141. (W.)	552
143		Complete individual, weight, 1013 pounds. (See Pl. III, Fig. 3.) Besides the shallow pits shown in the figure the mass is indented by deeper cylindrical ones, three to four cm. in depth. (W.)	460,304
144		Full-sized slab with polished and etched surfaces. The W. f. are very coarse, arranged in approximately parallel bands. Large nodules of troilite and flakes of schreibersite are scattered through the mass. (W.)	2,934
145		*Small, complete individual, like No. 141. (W.)	165
146		Complete individual weighing 265 pounds. (See Pl. III, Fig. 3.) The chain by which it is suspended passes through a natural perforation about 3 cm. in its smallest diameter. (W.)	120,657
147		*Full-sized slab showing polished and etched surfaces like No. 144. (W.)	4,309
148		Nearly complete individual showing deep and shallow pits. One etched surface exhibits nodules of troilite and indications of crystalline structure. (W.)	23,590
149		Complete individual, sub-cylindrical in form. Exhibits the characteristic pittings. (K.)	90,898
150		Thick slab, polished, showing nodules of troilite. (K.)	26,047
151		Hemispheroidal mass. One polished surface shows troilite nodules. (K.)	24,489
152		*One large and several small fragments with natural surface. (K.)	1,814
373		*Complete individual showing pits and natural surface. Apparently scaled from a larger mass. (W.)	670
	Found 1893.	**El Capitan Mts.,** New Mexico.	
430		Slab showing crust and polished surface. (By exchange with E. E. HOWELL.)	214

ÄEROSIDEROLITES OR IRON-STONE METEORITES.

Cat. No.	Date of Fall or Find.	NAME AND DESCRIPTION.	Weight in grams.
	Found 1749.	**Medwedewa, Krasnojarsk,** Siberia.(The Pallas Iron.)	
157		Fragment of the iron matrix with a little olivine. (W.)	9
158		Chiseled fragment showing both iron and olivine. (K.)	12.5
159		*Several fragments, composed of iron and olivine. (K.)	76.5
	Found about 1800.	**Imilac, Desert of Atacama,** South America.	
160		Fragment of iron matrix, most of the stony filling having decomposed and dropped out. (W.)	12.5
161		*Like previous specimen. (W.)	28.5
162		Thick slab, polished and etched. The metallic portion exhibits occasional W. f. Its sponge-like pores are filled with olivine, more or less decomposed. (W)	205
	Found 1847.	**Rittersgrün,** Erzgebirge, Saxony.	
164		Thin slab, polished. The stony portion exceeds the metallic. (W.)	33.5
	Found 1856.	**Hainholz, Minden,** Westphalia.	
165		Thin chip, showing natural and polished surface. The metallic grains are small, and scattered through a brownish mass of asmanite and bronzite. (W.)	10.5
267		*Fragment from interior. Black, fine-grained. (W.)	1.3
75		*Like No. 165, but more decomposed. (K.)	19
	Found 1857.	**Miney, Taney Co.,** Missouri.	
166		Slab showing natural and polished surfaces. The natural surface has the peculiar glaze characteristic of this meteorite. (K.)	60
167		Sawed slab showing natural and polished surfaces. The metallic and non-metallic minerals are about equally abundant. (W.)	395
168		*Like previous specimen except that the olivine is gathered in large nodules in certain portions. (W.)	209
77		*Fragment with natural surface. (W.)	4
	Found 1861.	**Breitenbach,** Platten, Bohemia.	
169		Thin, polished slab. Resembles the Rittersgrün specimens very closely. (W.)	1
	Found 1862.	**Sierra de Chaco, Desert of Atacama,** South America.	
170		Fragment with crust. Structure fine-granular, with metallic and non-metallic minerals about equally distributed. (W.)	17.5
171		Similar to No. 170, except that the surface appears glazed and shines in iridescent colors. (W.)	14.5

ÄEROSIDEROLITES OR IRON-STONE METEORITES.

Cat No.	Date of Fall or Find.	NAME AND DESCRIPTION.	Weight in grams.
	Found 1874.	**Mejillones,** near Desert of Atacama, South America.	
172		Thin, polished slab. The nickel-iron is distributed in a fine network and occasional nodules through an amorphous ground-mass. (W.)	37
	Fell 1879, May 10. 5 P. M.	**Estherville, Emmett County,** Iowa.	
175		Four complete individuals, varying in size from that of a pea to that of a walnut. The surface shows rounded knobs, and is partly of the color of blued steel and partly nickel-white. (K.)	70
176		Irregular fragment, much oxidized. (W.)	75
177		Full-sized slab, polished. The iron appears in large nodules, irregular flakes and a long, narrow vein, distributed through a greenish-black, structureless ground-mass. (W.)	2,721
178		*Thirteen complete individuals, varying in size from that of a pea to that of a walnut. Surface like No. 175. (W.)	47
	Found 1880.	**Carroll County,** (Eagle Station), Kentucky.	
180		Sawed slab showing natural surface deeply pitted, and polished surface. The iron matrix encloses nodules of olivine, some a centimeter in diameter, transparent, and of brilliant lustre. (K.)	106
182		Grains of olivine, separated from the iron, some coarse and some in a powdered state. (K.)	96
	Found 1885.	**Pavlodar,** Semipalatinsk, Asiatic Russia.	
183		Polished fragment, made up principally of olivine enclosed in an iron matrix. Also some loose grains of olivine. (W.)	15
	Found 1887.	**Rockwood, Cumberland Co.,** Tennessee.	
184		From Mass No. 1. Thin slab showing natural and etched surfaces. The metallic grains are small and about evenly distributed, except for three large nodules, one of which, having a diameter of 1.5 cm. shows well marked W. f. The metallic portion serves as a matrix to hold the siliceous grains. (W.)	40.5
185		Mass No. 2. Complete individual. The crust is reddish-brown and cracked in several places. No well-marked pits are seen. (W.)	4,351
186		From Mass No. 3. One-half of the original find, with natural and polished surface. General structure like No. 184, but the specimen shows a larger proportion of the non-metallic minerals, and these occur occasionally in large nodules. (W.)	801
187		From Mass No. 1 (?). Large segment showing natural and polished surfaces. Structure like No. 186. (W.)	6,151
374		*Segment of complete individual, showing natural and polished surfaces. Structure like No. 184. (W.)	670

AEROSIDEROLITES OR IRON-STONE METEORITES.

Cat. No.	Date of Fall or Find.	NAME AND DESCRIPTION.	Weight in grams.
	Found 1887.	**Powder Mill Creek,** Crab Orchard Mts., Tennessee. (Identical with Rockwood.)	
336		Irregular fragment, one surface polished. Metallic grains small and evenly distributed. (K.)	80.4
	Found 1888.	**Llano del Inca,** Desert of Atacama, So. America.	
188		*Dark-brown mass, with natural and polished surfaces. Metallic grains appear only on one edge.	38
189		Complete individual, intersected by the cracks so characteristic of this meteorite. A few large grains of olivine are enclosed in cavities on the surface. (W.)	54.5
190		Thick slab, polished on two surfaces. No metallic grains are visible. (W.)	148
	Found 1888.	**Dona Inez,** Desert of Atacama, So. America.	
191		Thin slab, showing natural and etched surfaces. The stony matter, dark-brown in color, largely predominates. One nodule of iron about the size of a pea, shows delicate W. f. (W.)	48.5
192		*Hemispheroidal mass, one surface polished. The peculiar cracked surface characteristic of these meteorites is well exhibited. (W.)	103
193		Complete individual, described by Howell as looking like "a lump of dried, red mud cracked by shrinkage and covered with spots of green mould (nickel) in places." (W.)	741
194		Similar to No. 192, but larger. (W.)	245
	Found 1890.	**Kiowa County,** (Brenham Township), Kansas.	
195		One-half of a complete individual, one surface polished. Composed chiefly of iron, with olivine filling the sponge-like pores. (W.)	2,061
196		Thin slab, polished. The central portion for a width of about 5 cm. is solid metal, but on either side the mass is porous, the pores being filled with olivine. (W.)	1,248
197		Full-sized slab, polished, showing a sponge-like mass of iron, with olivine filling the cavities. See Plate IV, Fig. 1. (K.)	2,048
198		Similar to No. 197, but thicker. Some of the olivine nodules are beautifully transparent and highly refracting. (K.)	8,117
199		*Smaller piece, similar to No. 197. (K.)	227
200		466 pound mass, entire. The form is flattened, somewhat heart-shaped. The surface is covered with pittings, and considerably oxidized. The grains of olivine are readily discernible over the surface. See Plate IV, Fig. 2. (K.)	218,847
201		*Full-sized slab, showing structure like No. 197. (K.)	5,895
202		18 pound mass, entire. Form, hemispheroidal, the surface covered with pittings. Structure porous, pores filled with olivine. See Plate IV, Fig. 3. (K.)	8,619

AEROSIDEROLITES OR IRON-STONE METEORITES.

Cat. No.	Date of Fall or Find.	NAME AND DESCRIPTION.	Weight in grams.
	Found 1890.	**Kiowa County,** (Brenham Township), Kansas.	
203		Section of complete individual, showing natural and polished surface. The structure is like that of No. 197. (K.)	8,490
204		345 pound mass, entire. This is almost wholly iron of the Caillite variety. Form, kidney or arch-shaped, with a projection extending from the concavity of the arch. See Plate IV, Fig.3.(K.)	155,473
205		36 pound mass, entire. Spheroidal in form, surface covered with pittings. Entirely metallic. See Plate IV, Fig. 3. (K.)	16,091
206		40 pound mass entire. Form, cylindrical, with one projecting point. Surface pitted. Composed almost wholly of iron, but occasional grains of olivine are visible. See Plate IV, Fig. 3. (K.)	17,687

ÄEROLITES OR STONE METEORITES.

Cat. No.	Date of Fall or Find.	NAME AND DESCRIPTION.	Weight in grams.
	Fell 1492, Nov. 16, 11:30 P. M.	**Ensisheim,** Elsass, Germany.	
207		Fragment from interior. Dark-gray, fine-grained, smooth and shining in portions. (W.)	22
208		Similar to previous specimen. (W.)	4
	Fell 1753. July 3 8 P. M.	**Krawin, Tabor,** Bohemia.	
209		Fragment from interior. Light-gray with rusty iron spots. (W.)	.06
	Fell 1768, Nov. 20, 4 P. M.	**Mauerkirchen,** Austria.	
210		Irregular fragment. Light-gray with black crust, 1 mm. in thickness. (W.)	17.5
211		Fragment with crust. Two polished surfaces show scattered metallic grains and well marked chondri. (K.)	110
	Fell 1785, Feb. 19.	**Wittmess, Eichstädt,** Bavaria.	
212		Two fragments from interior, showing a gray, coarse ground-mass containing rusty iron grains. (W.)	1.7
	Fell 1790, July 24, 9 P. M.	**Barbotan,** Landes, France.	
213		Fragment from interior, one surface polished, showing numerous, minute, metallic grains. (W.)	6
214		Fragment with crust, showing pitted surface. Much discolored by age. (K.)	32
	Fell 1795, Dec. 13, 3:30 P. M.	**Wold Cottage,** Thwing, Yorkshire, England.	
215		Three polished chips, showing chondri and metallic grains, both coarse and fine. (W.)	2
	Fell 1789, Dec. 13, 8 P. M.	**Krakhut, Benares,** India.	
216		Powder, showing crust and individual chondri. (W.)	.71
217		Fragment with crust. One surface polished, showing scattered metallic grains. (W.)	1
	Fell 1803, April 26, 1 P. M.	**L'Aigle,** Normandie, Orne, France.	
218		Gray powder. (W.)	.25
219		Fragment with crust The latter thin, reddish brown, smooth. Interior grayish-brown, compact, porphyritic in appearance. (W.)	111
220		Fragment with crust and polished surface. The polished surface shows a few fine, metallic grains. Through a dark, amorphous ground-mass are mingled grayish-white nodules of various sizes. (K.)	60
	Fell 1806, Mar. 15, 5 P. M.	**Alais,** Gard, France.	
221		Coarse, brown-black powder, resembling an earthy coal. Very friable. (W.)	1
222		Interior fragment like previous specimen. (K.)	0.4
	Fell 1807, Dec. 14, 6:30 A. M.	**Weston, Fairfield Co.,** Connecticut.	
224		Fragment with crust. The latter thin, dull-black. The yellowish and bluish-gray portions of the interior are distinctly separated. The chondri, of which the mass is largely made up, give it the appearance of a fine conglomerate. (W.)	9

ÄEROLITES OR STONE METEORITES.

Cat. No.	Date of Fall or Find.	NAME AND DESCRIPTION.	Weight in grams.
225	Fell 1808, May 22, 6 A. M.	**Stannern, Iglau,** Moravia. Fragment from interior. Light-gray. Structure coarse-granular, not chondritic. (W.)	7.5
226		Fragment with crust; the latter glossy-black, veined. Interior greenish-black, brecciated. Shows one large grain of troilite. (W.)	23.5
227		*Fragment from interior, similar to No. 225. (W.)	1.5
228	Fell 1810, Aug., 12 M.	**Mooresfort, Tipperary,** Ireland. Fragment with crust. Crust black, somewhat shining. Interior, compact, ash-gray. Shows coarse, metallic grains and white chondri. (K.)	7
229	Fell 1810, Nov. 23, 1:30 P. M.	**Charsonville,** near Orleans, Loiret, France. Fragment from interior. Light-gray, with rusty-brown spots, due to the oxidation of the abundant metallic grains. (W.)	22
230		Thin chip, polished. Like previous specimen, but traversed by a delicate, black vein. (W.)	2
231	Fell 1812, Apr. 15, 4 P. M.	**Erxleben, Magdeburg,** Prussia. Fragment from interior. Dark-gray, compact, made up of siliceous grains with a vitreous lustre, and numerous fine, metallic grains. (W.)	2.5
232	Fell 1812, Aug. 5, 2 A. M.	**Chantonnay,** Vendée, France. Thin chip, highly polished. Almost black, with few metallic grains. Structure not discernible megascopically. (W.)	2
233	Fell 1813, Sept. 10, 6 A. M.	**Limerick, Adare,** Ireland. Thin chip, polished. Dark-gray, with thickly distributed rusty iron flakes. (W.)	1.5
234	Fell 1814, Sept. 15, Noon.	**Alexejewka, Bachmut,** Ekaterinoslav, Russia. Fragment with crust and polished surface. Crust dull-black. Interior light-gray, with a few rusty grains. (W.)	12
235	Fell 1814, Sept. 5, Noon.	**Agen,** Lot-et-Garonne, France. Fragment from interior, showing white chondri and metallic grains distributed through a darker ground mass. (W.)	0.5
236	Fell 1819, Oct. 13, 8 A. M.	**Politz.** near Gera, Reuss, Germany. Fragment from interior. Dark gray, with metallic grains. (W.)	0.5
237	Fell 1821, June 15, 3:30 P. M.	**Juvinas,** Ardeche, France. Three fragments from interior. Dark-gray. Structure not well defined. No metallic grains visible. (W.)	12
238	Fell 1825, Feb. 10, 12 M.	**Nanjemoy,** Charles Co., Maryland. Fragments from interior. Light-gray, fine-grained, somewhat friable. Metallic particles thickly distributed. (W.)	0.5

ÄEROLITES OR STONE METEORITES.

Cat No.	Date of Fall or Find.	NAME AND DESCRIPTION.	Weight in grams.
239	Fell 1828, June 4, 8:30 A. M.	**Richmond,** Henrico Co., Virginia. Fragment from interior. Composed chiefly of dark, angular, vitreous and coarse metallic grains. (W.)	2
240	Fell 1829, May 8, 3:30 P. M.	**Forsyth,** Monroe Co., Georgia. Thin chip, polished. Ground mass brownish-gray, containing chondri of lighter color, and scattered fine metallic grains. Also smaller fragments. (W.)	5
241		Fragment with crust. Crust black, dull and thick. Interior like previous specimen. (K.)	34
242	Fell 1831, July 18.	**Vouille,** Poitiers, Vienne, France. Fragment with crust. Interior, gray, compact, flecked with rusty iron grains. Several delicate, black veins, apparently filled with metal, traverse the specimen. Smaller fragments. (K.)	53
243		*Thin chip, polished. Well-marked chondri make up the larger part of the mass. Fine metallic grains are numerous. (W.)	3
354	Fell before 1838.	**Simbirsk,** Partsch, Russia. Micro-section. See Pl. VI, Fig. 1. (W,)	
245	Fell 1838, June 6, Noon.	**Chandakapur,** Beraar, India. Three fragments from interior, two of them polished, showing a dark-gray stone, containing numerous rusty iron grains. (W.)	3.5
246	Fell 1838, Oct. 13, 9 A. M.	**Cold Bokkeveld,** Cape of Good Hope, Africa. Fragment from interior. Dull-black, with white specks. Resembles a piece of graphite or bituminous coal. (W.)	1
249	Fell 1841, June 12, 1:30 P. M.	**Chateau Renard,** Loiret, France. Fragment from interior. Gray, compact, traversed by black, delicate veins. Metallic grains small and bright (W.)	57
248		*Like previous specimen. (W.)	7
247		*Like No. 249. (W.)	5
250	Fell 1842, Apr. 26, 3 P. M.	**Pusinsko Selo,** Milena, Croatia. Fragment from interior. Light-gray, with coarse and fine metallic grains. Shows distinct chondritic structure. (W.)	6
251	Fell 1843, March 25.	**Bishopville,** South Carolina. Fragment from interior. Light-gray, with white nodules of the chladnite of Shepard. Rusty brown spots show the presence of metallic grains. (W.)	1
252		Like previous specimen, but showing vitreous crust. (W.)	2
253		Fragments of chladnite. (K.)	5

ÄEROLITES OR STONE METEORITES.

Cat No	Date of Fall or Find.	NAME AND DESCRIPTION.	Weight in grams.
254	Fell 1846, Dec. 25, 2:45 P. M.	**Schönenberg, Swabia,** Bavaria. Fragment with crust. The latter is thick, somewhat shining and scoriaceous. The interior is dark-gray, shows metallic grains and light and dark chondri, and is traversed by narrow, branching veins of nickel-iron. (K)	17
255	Fell 1847, Feb. 25, 2:45 P. M.	**Hartford, Linn Co.,** Iowa. Mass with crust. The crust, thick and dull black, is intersected by numerous cracks. Interior pearl-gray, abounding in minute iron grains. Delicate lines of fracture, which traverse the specimen, seem to mark slipping zones with slicken-sided surfaces. (W.)	128
256	Fell 1849, Oct. 31, 3 P. M.	**Monroe, Cabarras Co.,** North Carolina. Fragment from interior. Dark-gray, with white, rounded chondri and numerous metallic grains. Compact. (W.)	4
257	Fell 1850, June 13,	**Kesen,** Iwate Prefecture, Japan. Mass showing crust and interior. The crust surface differs little from the interior, except that the metallic grains of the former have been blackened by fusion, and broad, shallow pits appear on this surface. The interior is dark-gray, compact and plentifully sprinkled with rusty iron grains A portion of the surface is smoothed and grooved, indicating slipping along these planes. (W.)	1,286
258		Similar to previous specimen, but showing elongated pits on the crust surface. (W.)	1,211
259	Fell 1852, Jan. 23, 4:30 P. M.	**Yatoor, Nellore,** Madras, India. Fragments from interior. Gray, with dark chondri and rusty iron grains. (W.)	1
260	Fell 1852, Sept. 4, 4:30 P. M.	**Fekete, *Mezo=Madaras*,** Transylvania. Polished fragment from interior. In the dark-brown ground-mass are sharply outlined gray and white chondri, interspersed with bright, minute grains of nickel-iron. (W.)	2
261		Like previous specimen, but showing rough, dull-brown crust, not sharply separated from the interior. (W.)	4
262	Fell 1852, Oct. 13, 3 P. M.	**Borkut, *Marmaros*,** Hungary. Individual chondri, spheroidal, dark-green in color. (W.)	0.12
263	Fell 1853, Feb. 10, 1 P. M.	**Girgenti,** Sicily. Polished fragments from interior. Gray, very fine-grained, with bright, metallic grains. (W.)	1.1

ÄEROLITES OR STONE METEORITES.

Cat. No.	Date of Fall or Find.	NAME AND DESCRIPTION.	Weight in grams.
264	Fell 1855, May 11, 3:30 P. M.	**Island of Oesel, Kaande,** Livland, Baltic Sea. Fragments with crust. Interior light-gray with rusty and bright metallic grains. Friable. Crust .5 mm. thick, dull-black, papillated. (W.)	2
265	Fell 1855, May 13, 5 P. M.	**Gnarrenburg, Bremervörde,** Hanover. Fragment from interior. Through a light, fine-grained ground-mass are scattered coarse particles of a greenish-black mineral. Few metallic grains. (W.)	0.5
268	Fell 1856, Nov. 12, 4 P. M.	**Trenzano,** Brescia, Italy. Cubical fragment, with crust on two surfaces. The latter shining, black, only slightly pitted, .3 mm. thick. Interior very compact, coarse grained, the metallic portion forming a network which encloses dark, spherical chondri, some of a diameter of 2 mm. (W.)	57
325		Smaller fragment, like previous specimen. (W.)	2
269		Like previous specimen. (W.)	26.5
270	Fell 1857, Feb. 28, Noon.	**Parnallee, Madras,** India. Fragment with crust. The latter is thin, brownish-black and differs little from the rest of the stone. The interior is coarse-grained, with few metallic grains. (W.)	3.5
271	Fell 1858, Dec. 9, 7:30 A. M.	**Ausson and Clarac,** Montrejeau, Haute Garonne, France. Fragment from interior. Light-gray, with rusty-iron grains. Compact. Delicate veins penetrate the mass. (W.)	13
272		Fragment from the interior, with polished surface. The latter shows large chondri of an olivine-like mineral, embedded in a ground mass made up chiefly of small white chondri and grains of nickel-iron. (K.)	22
273	Fell 1860, May, 1, 12:45 P. M.	**New Concord, Muskingum Co.,** Ohio. Nearly complete individual, of flattened, tetrahedral form, angles little rounded. A smooth, somewhat shining, black crust covers the slightly pitted surface. Interior dark-gray, compact and fine-grained. Metallic grains numerous. (W.)	347
274		Section from flattened individual, showing crust and two polished surfaces. The crust is thin, dull-black to reddish. A vein of metallic matter runs through the mass, and stands out in relief from the crust. The interior of the stone is dark-brown and gray. Metallic grains are large and abundant. (W.)	753

ÄEROLITES OR STONE METEORITES.

Cat. No.	Date of Fall or Find	NAME AND DESCRIPTION.	Weight in grams.
	Fell 1860, July 14, 2:30 P. M.	**Dhurmsala,** Kangra, Punjaub, India.	
275		Fragments from interior. (K.)	5
276		Fragment with crust, the latter black, shining and showing numerous pits. Interior light-gray, with rusty grains. Compact. Nodules of a bluish gray, finer grained than the rest, are distributed through the mass. (W.)	123
	Fell 1861, May 12.	**Butsura,** Goruckpur, India.	
277		Fragments with crust and polished surfaces. Iron is present in large amount, forming a matrix in which are held chondri 1 mm. in diameter, of an olivine-like mineral. The rest of the groundmass is greenish-black, structureless. (W.)	1.85
	Fell 1861, Oct. 7, 1:30 P. M.	**Klein=Menow,** Alt-Strelitz, Mecklenberg.	
278		Fragment from interior, made up of coarse, transparent grains with rusty metallic ones, the whole resembling a piece of brown sandstone. (W.)	2
	Fell 1863, Aug. 8, 12:30 P. M.	**Aukoma, Pillistifer,** Livland, Russia.	
279		Fragment from interior. Dark-gray, compact. Made up of dark, transparent grains with a large number of minute specks of troilite. (W.)	1
	Found 1863-4	**Tomhannock Creek,** Rensselaer Co., New York.	
280		Fragment from interior, polished. Made up chiefly of metallic grains, and a dark-brown, olivine-like mineral. (W.)	1
281		Slice, showing crust. Interior portion like previous specimen. (W.)	7.5
	Fell 1864, May 14, 8 P.M.	**Orgueil, Montauban,** Tarn et Garonne, France.	
282		Coarse, black powder, somewhat friable. (K.)	1.18
	Fell 1865, Aug. 25, 11 A. M.	**Aumale, Senhadja,** Algeria, Africa.	
283		Slice from interior. Ash-gray, few metallic grains. Chondritic structure. (W.)	1.5
	Fell 1866, June 9, 5 P. M.	**Knyahinya,** near Nagy-Berezna, Hungary.	
284		One-half of a complete individual, showing crust and polished surface. The latter exhibits large and small chondri, with few metallic grains. (W.)	82
285		Complete individual, covered with thin, black crust. (W.)	10
286		Complete individual, mostly covered with black, somewhat shining crust. Surface indented with shallow pits. (W.)	239
287		Flattened mass, showing crust and one polished surface. The crust surface is smooth and covered with small, conical pittings, giving to it the appearance of having a cellular structure. The polished surface well exhibits the aggregation of chondri which make up the mass of the stone. Some of the chondri reach a diameter of 3 mm. (K.)	3,231

ÄEROLITES OR STONE METEORITES.

Cat. No.	Date of Fall or Find.	NAME AND DESCRIPTION.	Weight in grams.
288	Fell 1866, June 9, 5 P. M.	**Knyahinya,** near Nagy-Berezna, Hungary. Complete individual, of irregular, pyramidal form, surface covered with shining black crust. (K.)	82.5
289	Fell 1868, Jan. 30, 7 P. M.	**Pultusk,** Siedlce, Gostkóv, &c., Poland. Part of a large individual, showing crust and interior. The former dull-black, papillated; the latter, gray with rusty iron grains. All fine-grained. (W.)	350
290		*49 complete individuals, varying in size from a pea to a walnut. All covered more or less with crust, in some cases showing complete fusion of the surface, in others only a smoking of the same. (W.)	435.5
291		*Seven complete individuals of larger size than previous specimens, Covered with crust. (W.)	445
293		Fragment from interior. (K.)	1.9
294	Fell 1868, July 11.	**Ornans,** Doubs, France. Fragment, sawed from interior. Resembles a lump of hardened, sandy mud. (K.)	5
295	Fell 1868, Sept. 8, 2:30 A. M.	**Sauquis,** St. Etienne, Basses-Pyrénées, France. Fragment with crust and polished surface. Crust black and shining, about 1 mm. in thickness. Interior brownish-gray, with scattered metallic particles. Also fragment without crust, and micro-section. (K.)	12
296	Fell 1868, Dec. 5.	**Frankfort, Franklin Co.,** Alabama. Thin, sawed fragment. Light-gray with black and white grains. No metallic particles visible.(W.)	0.5
297	Fell 1869, Jan. 1, 12:30 P. M.	**Hessle,** near Upsala, Sweden. Sawed fragment, with thin, dull-black crust. Metallic grains coarse and numerous. (W.)	18
298		Fragment showing crust on all but two surfaces. (K.)	5
299	Fell 1869, May 22, 10 P. M.	**Kernouve, Cléguérec,** Morbihan, France. Fragment from interior. (W.)	0.4
300		Thin chip, one surface polished. Dark-gray, metallic and stony materials about equally distributed. (W.)	2
301		Thin, polished fragment. (W.)	24
302	Fell 1871, May 21, 8:15 A. M.	**Searsmont,** Waldo Co., Maine. Fragment from interior. Light-gray. (W.)	0.25
303		Various fragments from interior. Light-gray, with metallic grains of silvery lustre. Chondritic structure. (K.)	3
304	Fell 1871, Dec. 10, 1:30 P. M.	**Bandong,** Goemoroeh, Java. Two fragments from interior. Grayish-brown. with metallic particles. (W.)	1.5

AEROLITES OR STONE METEORITES.

Cat. No.	Date of Fall or Find.	NAME AND DESCRIPTION.	Weight in grams.
	Found 1872.	**Waconda,** Mitchell Co., Kansas.	
309		*Mass from interior. Larger part light-gray in color, the remaining portion harder and darker. Large chondri are visible in the latter. (W.)	2,835
310		Fragment with crust. The latter thin, dull-black, blebby. A dark vein passes through a portion of the specimen. (W.)	151.5
311		*Fragment from interior, much weathered. (K.)	5.5
	Fell 1873, June.	**Jhung**, Punjaub, India.	
305		Fragment from interior. Grayish-brown, coarse grained, chondritic, metallic particles few and small. (W.)	4
306		Thin, polished fragment, showing characters like previous specimen. (W.)	2.5
	Fell 1874, May 14, 2:30 P. M.	**Nash Co.,** near **Castalia,** North Carolina.	
307		Fragment with crust; the latter dull-black and scoriaceous. The color of the stone is dark-gray, with no metallic grains visible. (W.)	1.5
308		Fragment from interior, showing occasional metallic grains. (W.)	6.5
	Fell 1875, Feb. 12, 10:15 P. M.	**Homestead, Iowa Co.,** Iowa.	
312		Complete individual, nearly covered with crust. Surface indented with broad, shallow pits. Crust thin, dull-black. Interior of stone dark-gray. (W.)	3,175
313		*About three-fourths of a complete individual. Crust and interior like previous specimen. The chondritic structure is well exhibited, and metallic grains are numerous. (W.)	7,626
314		Polished slab with crust. The abundance of metallic constituents is well displayed in this specimen, as are also the chondri. (W.)	1,744
	Fell 1876, June 28, 11:30 A. M.	**Ställdalen,** Orebro, Sweden.	
315		Fragment with crust. The latter black and shining. Interior of the stone dark-gray. (K.)	5
316		Irregular mass, with crust. Interior oxidized to a brownish-black mass, amid which it is difficult to distinguish the structural features. (K.)	50
	Fell 1877, Jan. 3.	**Warrenton,** Warren Co., Missouri.	
317		Fragment from interior. Resembles a piece of hardened, sandy mud or blue clay, with a few metallic grains visible. (W.)	5
	Fell 1877, Oct. 13, 2 P. M.	**Sarbanovac, Soko-Banja,** N.-E. of Alexinatz, Servia.	
319		Irregular fragment, of light-gray color, showing chondri about 2 mm. in diameter through the mass, also nodules of troilite and metallic grains. (W.)	33

ÄEROLITES OR STONE METEORITES.

Cat. No.	Date of Fall or Find	NAME AND DESCRIPTION.	Weight in grams.
	Found 1878.	**Fayette,** Texas.	
173		About one-tenth the original mass, showing crust and polished surface. The crust surface is somewhat decomposed, but shows the characteristic pittings. The polished surface shows the dark-green color of the stone, with its fine texture and scattered metallic grains. (W.)	10,985
174		Thin slab from another portion of the specimen, exhibiting the black veins peculiar to this meteorite. (W.)	2,934
	Fell 1879. Aug. 1, Evening.	**Nagaya, Entre Rios,** Argentina, South America.	
320		Small fragment, entirely black in color, one surface having a scoriaceous appearance, the remainder the lustre of graphite. (W.)	10
	Fell 1880. June 30.	**Carbonaceous Meteorite,** Province of **Entre Rios,** Argentina, South America.	
321		Several fragments, having much the appearance of bits of black lava. (W.)	0.5
	Fell 1882, Feb. 3, 4 P. M.	**Mocs,** Kolos, Transylvania.	
322		Nearly complete individual, cuboidal in form, with solid angles only slightly rounded. Interior grayish-brown in color, with coarse, metallic grains. (W.)	179
323		Elongated fragment, showing crust on two sides. Narrow, dark veins similar to those noted by Tschermak, pass through the mass in several directions. (W)	41
324		*Six fragments of nearly equal size, showing crust and interior. They have in general a cuboidal form with a prominence of the solid angles. Portions of the interior display a "slickensided" surface. (W.)	543
330		Complete individual, tetrahedral in form. Entirely covered with thick, black crust, except at one point, where the light-gray interior may be seen. (K.)	80.5
331		Complete individual, plano-convex in form, the convex surface being evidently the "breast" side. The opposite face shows a thinner crust and rougher surface. (K.)	6
	Fell 1883, Feb. 16, 3 P. M.	**Alfianello,** Brescia, Italy.	
332		Fragment, with crust. The latter is about 0.4 mm. in thickness, and of a dirty black color. The interior of the stone is ash-gray, fine-grained, and contains metallic grains, with some coarse nodules of the same. (W.)	24
333		*Interior fragment, ash-gray, with brown spots, due to the oxidation of the metallic particles. Several of the latter are quite large, and rounded as if previously fused. (W.)	134.5

AEROLITES OR STONE METEORITES.

Cat. No.	Date of Fall or Find	NAME AND DESCRIPTION.	Weight in grams.
334	Fell 1883, Feb. 16, 3 P. M.	**Alfianello,** Brescia, Italy. *Large fragment, with crust. Characters like those of previous specimen. (K.)	300
335	Fell 1887, Aug. 30.	**Taborg,** Ochansk, Perm, Russia. Fragment with crust. The latter about 1 mm. thick, dull-black and blebby. Interior of stone light bluish-gray. Shows brecciated structure. Fine metallic grains are numerous. (W.)	23.5
337	Found 1888.	**Pipe Creek,** Texas. Irregular fragment, with one polished surface. A dark, heavy stone, with a large proportion of metallic grains. (K.)	100
338	Fell 1889, June 9.	**Mighei,** Southern Russia. Fragment, with crust. Of dark color, somewhat resembling a piece of graphite, and so friable as to soil the fingers. Crust reddish and scoriaceous. (W.)	1.5
339		Like previous specimen, except that crust is darker. Chondri of lighter color are distributed through the mass. (K.)	4.4
340	Fell 1890, May 2, 5:15 P. M.	**Leland, Winnebago Co.,** Iowa. 609 complete individuals, ranging in weight from one-tenth of an ounce to ten pounds each. They exhibit almost every variety of shape and degree of surface fusion. From the fully rounded specimens with thick, black crust there is every gradation to those whose rough surface is only slightly blackened, indicating that they separated from other masses only a short distance before reaching the earth. The interior, where seen, is light gray, with coarse, metallic particles. In the group is the stone which fell into a haystack without setting it on fire. (See Pl. V, Fig. 2.) (K.)	15.823
341		*57 complete individuals, all of small size. (W.)	354
326		Complete individual, with small, conical pittings resembling rain drop impressions. (W.)	282
342	Fell 1890, June 25, 1 P. M.	**Farmington, Washington Co.,** Kansas. Fragment from interior, having the appearance of a dolerite of dark-gray color and splintery fracture. Contains white, radiated chondri. Bronze-yellow metallic grains are numerous. (W.)	120
343		*Like previous specimen, but showing smooth crust which can be readily scaled off in certain spots. (W.)	560
344		Thin slab, polished, showing white and dark chondri, and various grains of nickeliferous iron. (W.)	425
345		*Similar to No. 343. (W.)	672
346		Full-sized slab, polished. Similar to above specimen. (W.)	3,302

ÄEROLITES OR STONE METEORITES.

Cat. No	Date of Fall or Find.	NAME AND DESCRIPTION.	Weight in grams
	Fell 1890, June 25, 1 P. M.	**Farmington, Washington Co.,** Kansas.	
347		Large section of complete individual, showing crust and one polished surface. The crust surface is rounded, but the usual pittings are absent. Bead-like projections mark the presence of metallic nodules which resisted fusion. (W.)	13,365
348		Full-sized slab, polished. The delicate veins filled with metal, noted by Preston, are beautifully exhibited in this specimen. (W.)	2,792
349		Nearly complete individual. The metallic beads on the surface are numerous, and the scale-like crust seems to be largely metallic. In other respects like previous specimen. (K.)	2,167
327		Section showing natural and polished surfaces. The latter shows several fissures filled with metal, running in two directions. (K.)	327
	Found 1891.	**Long Island, Phillips Co.,** Kansas.	
350		Nearly complete individual, made up of four pieces which have been placed together along the line of original fracture. The other 2,930 pieces, varying in weight from 10,000 grammes to 5 grammes, were probably also a part of the same individual at the time it fell to the earth. The surface of the main mass is indented by shallow, elliptical pits, the long axes of which run in parallel directions. The crust is smooth and brown, but in many places coated with a white incrustation of carbonate of lime, derived from the soil in which the stone lay. The interior of the mass shows a very compact, fine-grained texture, with few metallic grains; color, blue-gray. The smaller fragments are much rusted by exposure. (K.)	534,467
	Fell 1892, Aug. 29.	**Bath,** South Dakota.	
351		Irregular fragment, with crust and polished surface. The crust surface is indented with broad, shallow pits. Crust, dull-black, papillated, not more than .3 mm. in thickness. Interior, grayish-brown, of fine-granular structure, containing minute metallic grains. A portion shows "slickensided" surface. (W.)	1,276
	Fell 1893, May 26, 3 P. M.	**Beaver Creek,** British Columbia.	
352		Fragment, with crust. Interior, dark gray, made up of small, glassy chondri, and fine metallic grains. (W.)	5.5
353		Like previous specimen. Crust dull black, about .3 mm. thick. (W.)	19
		(DATE NOT KNOWN.)	
		Terni, Italy.	
356		Fragment, with crust. Crust dull-black, scoriaceous, nearly .2 mm. in thickness. Interior of stone light bluish-gray. Shows chondri and metallic grains. (W.)	2.5

ÄEROLITES OR STONE METEORITES.

Cat. No.	Date of Fall or Find.	NAME AND DESCRIPTION.	Weight in grams.
		Rockport.	
355		Plano-convex mass, showing crust and polished surface. Crust reddish brown, about 1 mm. thick. Interior greenish-black, exhibiting no megascopic structure except scattered metallic grains and nodules. (W.)	72

CASTS OF METEORITES.

About 50 casts or models of meteorites are exhibited illustrating the size, form and superficial appearance of the original masses of which some of the specimens in the cases formed a part.

The following is a list:—

380—La Bella Roca, Mexico.
381—Wold Cottage, England.
382—Durala, India.
383—Babb's Mill, Tennesee.
384—Wichita County, Texas.
385—Nagy-Diwina, Hungary.
386—Akburpur, India.
387—Chesterville, S. C.
388—Braunau, Bohemia.
389—Nellore, India.
390—Segowlie, India.
391—Sarepta, Russia.
392—Verkhne Udinsk, Siberia.
393—Parnallee, India.
394—Staunton, Virginia.
395—Khiragurh, India.
396—New Concord, Ohio.
397—Breitenbach, Bohemia.
398—Butsura, India.
399—El Chanaralino, Chile.
400—Juncal, Chile.
401—Allan Co., Kentucky.
402—Goalpara, India.
403—Krähenberg, Bavaria.
404—Homestead, Iowa.
405—Middlesborough, England.
406—Hex River Mountains, S. Africa.
407—Joe Wright Mountain, Arkansas.
408—Glorieta Mountain, New Mexico.
409—Puquios, Chile.
410—East Tennesee.
411—Cabin Creek, Arkansas.
413—Rockwood No. 2. Tennesee.
414—Rockwood No. 3. Tennesee.
415—Hamilton Co., Texas.
416—Welland, Canada.
417—Kenton Co., Kentucky.
418—Kiowa Co., Kansas.
419—Washington Co., Kansas.
420—Cacaria, Durango, Mexico.
422—Chupaderos, Chihuahua, Mexico. 15,000 Kg.
423—Chupaderos, Chihuahua, Mexico. 9,000 Kg.
424—San Gregorio, Chihuahua, Mexico.
425—La Concepcion, Chihuahua, Mexico.
426—Descubridora, Catorze, Mexico.
427—Zacatecas, Mexico.
428—Teposcolula, Mexico.

INDEX TO METEORITES.

Adare, see Limerick
Aeriotopos, see Bear Creek
Agen 50
Aigle, see L'Aigle
Akburpur 61
Alais 23, 28, 49
Albacher Mühle 36
Alexejewka 50
Alexinatz, see Soko-Banja
Alfianello 57, 58
Allen County 21, 40, 61
Arva 37
Atacama 22, 23, 45, 46, 47
Auburn, see Macon County
Augusta County, see Staunton
Aukoma, see Pillistfer
Aumale 54
Ausson and Clarac 53

Babb's Mill 15, 61
Bachmut 50
Bahia 35
Bandong 55
Barbotan 49
Bates County 19, 21, 40
Bath 13, 27, 59
Batsura, see Butsura
Bear Creek 21, 40
Beaver Creek 59
Bembdego, see Bahia
Benares, see Krakhut
Bishopville 24, 25, 51
Bitburg 36
Bluff, see Fayette
Bois de Fontaine, see Charsonville.
Bokkeveld, see Cold Bokkeveld
Borkut 52
Braunau 19, 22, 38, 61
Brazos, see Wichita County
Breitenbach 45, 61
Bremervörde, see Gnarrenburg
Bridgewater, 43
Burke County 43
Burlington 36
Busti 24
Butcher Irons, see Coahuila
Butler, see Bates County
Butsura 15, 54, 61

Cabarras County 52
Cabin Creek 61
Cacaria 61
Campo de Pucará, see Imilac
Cañon Diablo 7, 14, 15, 20, 44
Cape of Good Hope 36
Caracoles, see Imilac
Carbonaceous meteorite 57
Careyfort 22, 37
Carroll County 23, 46
Carthage 38
Castalia, see Nash County
Catorce, see Descubridora
Chandakapur 51
Chantonnay 27, 50
Charcas 36
Charlotte, see Dickson County
Charsonville 27, 50
Charlottetown, see Cabarras County
Chartres, see Charsonville
Chassigny 24
Chateau-Renard 51
Chattooga County 43
Chester County 38
Chesterville 21, 38, 61
Chulafinnee 40
Chupaderos 7, 16, 61
Clarac, see Ausson and Clarac
Cleburne County, see Chulafinnee

Cléguérec 55
Cleveland 41, 61
Coahuila, see Sancha Estate and Butcher Irons
Cocke County 37
Cold Bokkeveld 27, 51
Collescipoli, see Terni
Coney Fork, see Carthage
Coopertown, see Robertson County.
Cosby's Creek, see Cocke County
Cranbourne 16, 39
Cross Timbers, see Red River
Cumberland County 46, 61

Dalton, see Whitfield County
DeKalb County, see Careyfort
Debreczin, see Kaba
Deep Springs Farm 38
Denton County 39
Denver County, see Bear Creek
Descubridora 35, 61
Desert of Atacama, see Atacama
Desert of Mapimi, see Mapimi
Dhurmsala 15, 54
Dickson County 37
Dona Inez 15, 47
Duralla 61

Eagle Station, see Carroll County
East Tennessee, see Cleveland
Eichstädt 49
El Capitan Mountains 44
El Chanaralino 61
Elbogen 35
Ellenboro 44
Elmo, see Independence County
Emmett County, see Estherville
Emmitsburg 39
Ensisheim 10, 49
Entre Rios 28, 57
Erxleben 50
Estherville 13, 22, 46

Faha, see Limerick
Fairfield County 49
Farmington 58, 59
Fayette 57
Fekete, see Meso-Madaras
Floyd County 14, 43
Forsyth 13, 26, 51
Frankfort, see Franklin County
Franklin County 24, 55
Frederick County 39

Gera, see Politz
Gibbs meteorite, see Red River
Girgenti 52
Glorieta Mountain 19, 42, 61
Gnarrenburg 53
Grand Rapids 13, 19, 41, 42
Goalpara 61
Green County, see Babb's Mill
Guernsey County, see New Concord

Hainholz 23, 45
Hamilton County 22, 43, 61
Hammond 42
Hartford, see Linn County
Hastings County 39
Hauptmannsdorf, see Braunau
Henry County 22, 43
Hessle 15, 55
Hex River Mountains 22, 41, 61
Homestead 23, 25, 56, 61

Ibbenbuhren 24
Iglau, see Stannern
Ihung, see Jhung
Imilac 45
Independence County 42
Indian Valley Township 43
Iowa County, see Homestead
Island of Oesel, see Oesel
Ivanpah, see San Bernardino County
Ixtlhuaca 36

Janacera Pass, see Mejillones
Jarquera, see Mejillones
Jenny's Creek 41
Jhung 56
Joe Wright Mountain 22, 42, 61
Jonzac 24
Juncal 40, 61
Juvinas 23, 24, 25, 50

Kaba 28
Kaande, see Oesel
Kendall County 43
Kenton County 22, 43, 61
Kernoure, see Cléguérec
Kesen 13, 14, 23, 27, 52
Khiragurh 61
Kiowa County 7, 22, 47, 48, 61
Klein-Menow 54
Knoxville, see Tazewell County

Knyahinya..... 13, 16, 25, 26, 54, 55
Köstritz, see Politz...............
Krähenberg 61
Krakhut.................... 11, 49
Krasnojarsk.......... 10, 22, 23, 45
Krawin, see Tabor...............

La Concepcion.................. 61
L'Aigle......................11, 49
La Bella Roca.................. 61
Lagrange, see Oldham County.....
Langenpiernitz, see Stannern......
Laramie County................ 43
Laurens County................ 39
Lear Iron...................... 42
Leland......................... 58
Lenarto................... 18, 36
Lexington County.............. 41
Libonnez, see Juvinas............
Limerick....................... 50
Linn County............. 15, 27, 52
Lion River................. 21, 38
Llano del Inca................. 47
Long Island.................... 59
Lontolaks...................... 24
Lucè Island.................... 11

Macon County.................. 40
Madoc......................... 39
Madras........................ 53
Magdeburg, see Erxleben.........
Magura, see Arva................
Manbhoom..................... 24
Mapimi, Desert of.............. 37
Marmaros, see Borkhut...........
Mauerkirchen.................. 49
Maverick County.......... 21, 22, 41
Medwedewa, see Krasnojarsk......
Mejillones..................... 46
Mezo-Madaras.................. 52
Middlesborough................ 61
Mighei........................ 58
Milena, see Pusinsko Selo........
Miljana, see Pusinsko Selo ....
Minden........................ 45
Miney 45
Misteca, see Oaxaca..............
Mocs.............. 13, 15, 27, 57
Monroe, see Cabarras County......
Montauban, see Orgueil ....
Mooresfort.................... 50
Murfreesboro................... 38
Muskingum County, see New Concord.........................

Nagaya........................ 57
Nagy-Diwina................... 61
Nagy-Vazsony.................. 43
Nanjemoy...................... 50
Nash County................... 56
Nellore.................... 52, 61
Nelson County................. 39
New Concord...... 13, 23, 25, 53, 61

Oaxaca........................ 36
Octibbeha County.............. 18
Oesel, Island of................ 53
Oldham County................ 40
Orange River 39
Orgueil.................... 28, 54
Ornans 55

Pallas Iron, see Krasnojarsk.......
Parnallee.................. 53 61
Pavlodar 46
Peterborough.................. 24
Phillips County...... 7, 13, 14, 16, 59
Pillistifer..................... 54
Pipe Creek..................... 58
Pohlitz, see Politz................
Politz......................... 50
Powder Mill Creek.............. 47
Pultusk............ 13, 15, 25, 55
Puquios............... 21, 42, 61
Pusinsko Selo.............. 26, 51
Putnam County 37

Red River.................. 16, 36
Richmond 51
Rittersgrün............ 22, 23, 45
Robertson County.......... 20, 40
Rockingham County........ 38, 40
Rockport...................... 60
Rockwood, see Cumberland County.
Rutherford County, see Ellenboro and Murfreesboro..............

St. Croix County............ 19, 42
St. Etienne.................... 55
Saltillo, see Sancha Estate........
San Bernardino County.......... 41
San Gregorio............... 7, 61
San Luis Potosi................ 36
San Pedro, see Sancha Estate.....

Sancha Estate 37
Sarbanovac, see Soko-Banja ....
Santa Catarina 18, 40
Santa Fe County 42
Santa Rosa, see Sancha Estate ....
Sarbonavac, see Soko-Banja ....
Sarepta 61
Sauquis 55
Schönenberg 25, 27, 52
Scottsville 40
Searsmont 55
Seeläsgen 21, 38
Segowlie 61
Seneca Falls 8, 38
Seneca River, see Seneca Falls ....
Senhadja, see Aumale ....
Sevier County, see Cocke County ....
Shalka 24
Sierra de Chaco 45
Silver Crown 21, 43
Simbirsk 51
Smith County 38
Smith's Mountain 40
Soko-Banja 56
Ställdalen 56
Stannern 13, 24, 25, 50
Staunton 20, 22, 39, 61
Stutsman County 21, 42
Swabia 52
Szlanicza, see Arva ....

Tabor 49
Taborg 27, 58
Taney County 45
Tazewell County 39
Teposcolula 61
Terni 59
Texas, see Red River ....
Thunda 42
Tipperary, see Mooresfort ....
Toluca 13, 17, 19, 20, 22, 35, 36
Tomhannock Creek 54
Trenton 40
Trenzano 13, 26, 53
Trigueres, see Chateau-Renard ....

Union County 38

Vaca Muerta, see Mejillones ....
Venagas, see Descubridora ....
Verkhne Udinsk 61
Vouillé 51

Waconda 27, 56
Walker County 37
Washington County, 13, 27, 40, 58, 59, 61
Wayne County 41
Welland 43, 61
West Liberty, see Homestead ....
Weston 26, 27, 49
Whitfield County 41
Wichita County 10, 37, 61
Winnebago County 13, 15, 16, 58
Wittmess, see Eichstädt ....
Wold Cottage 11, 49, 61

Xiquipilco, see Toluca ....

Yanhuitlan, see Oaxaca ....
Yarra Yarra River, see Cranbourne.
Yatoor, see Nellore ....
Youndegin 22, 42

Zacatecas 36, 61

GENERAL INDEX.

Acoustic phenomena 9, 11, 14
Äerolites
  Definition 18
  Description of 23
  Classes of 24
  Analyses of 25
Äerosiderites.
  Definition of 18
  Analyses of 19
  Description of 18–22
Äerosiderolites.
  Definition of 18
  Description of 22–23
  Analyses of 23
Amphoterite 24
Analyses 19, 23, 25
Asiderites 18, 23
Awaruite 19

Basalt 24
Biela's comet 29, 30
Bustite 24

Carbonaceous meteorites 17, 27
Chassignite 24
Chladnite 24
Chondri 26
Chondritic structure 26
Classes of meteorites 18
Cleavage 22
Compounds in meteorites 17
Crust 13
Crystalline structure 19–21

Diogenite 24
Distribution of meteorites 12
Dunite 24

Effects of heat 13, 14
Elements in meteorites 16
Etching figures, see Widmanstätten figures
Eukrite 24

Evidences of life 28

Faults 27
Forms of meteorites 15

Gabbro 24
Gases in meteorites 18

Holosiderites 18
Howardite 24

Kamacite 17, 20

Laphamite markings 20
Lawrencite 17
Lherzolite 24
Luminous phenomena 9, 11, 14

Meteoric "fall" 12
Meteoric "find" 12
Minerals of meteorites 17

Origin of meteorites 28
Ovifäk iron 7

Pallasites 22
Pits 13
Plessite 17, 20

Saxonite 24
Schreibersite 17, 19, 22
Shooting stars 30
Size of meteorites 16
Slickensides 27
Specific gravity 19, 23, 26, 30
Sporadosiderites 18, 23
Syssiderites 18

Taenite 17, 20
Terrestrial iron 7, 19, 20, 30
Thumb marks 13
Times of fall 12
Troilite 17, 22

Veins 27
Velocity of meteorites 15

Widmanstätten figures 20, 21

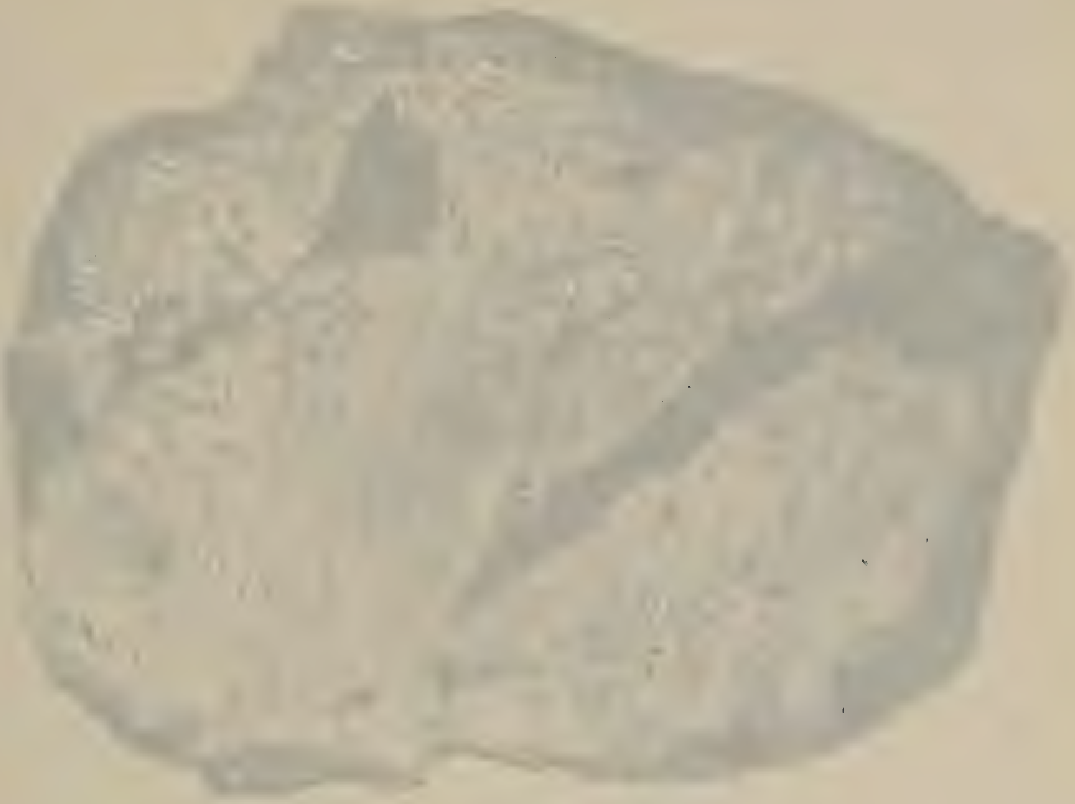


FIG. 1

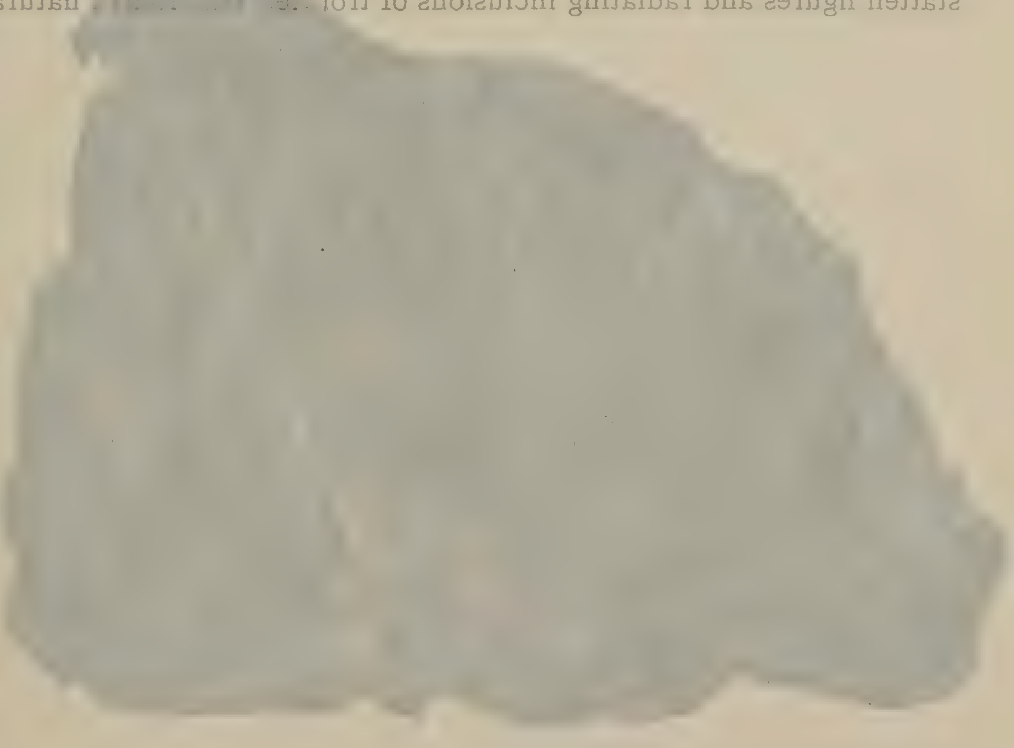


FIG. 2 Hamilton Co., Texas.

PLATE I.

Fig. 1. Äerosiderite, Toluca, Mexico. Etched slab showing coarse Widmanstätten figures and elongated nodules of troilite. One-half natural size.

Fig. 2. Äerosiderite Hamilton Co., Texas. Etched slab showing delicate Widmanstätten figures and radiating inclusions of troilite. One-fourth natural size.

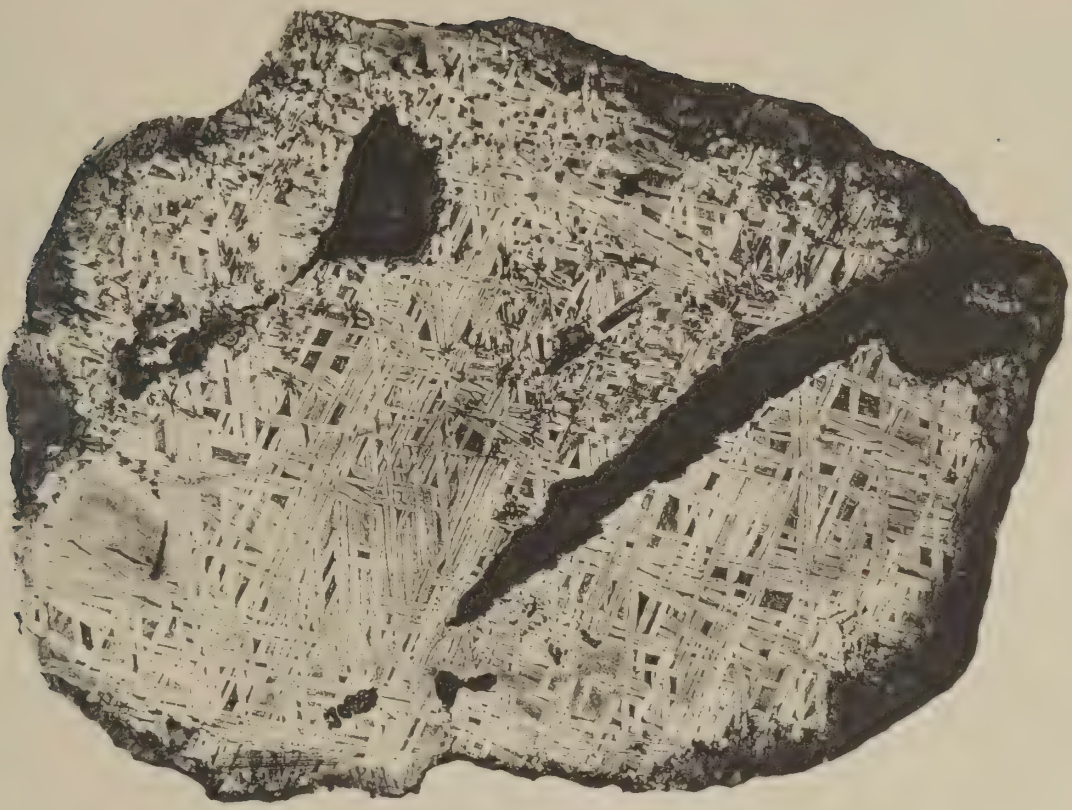


FIG. 1. Toluca, Mexico.

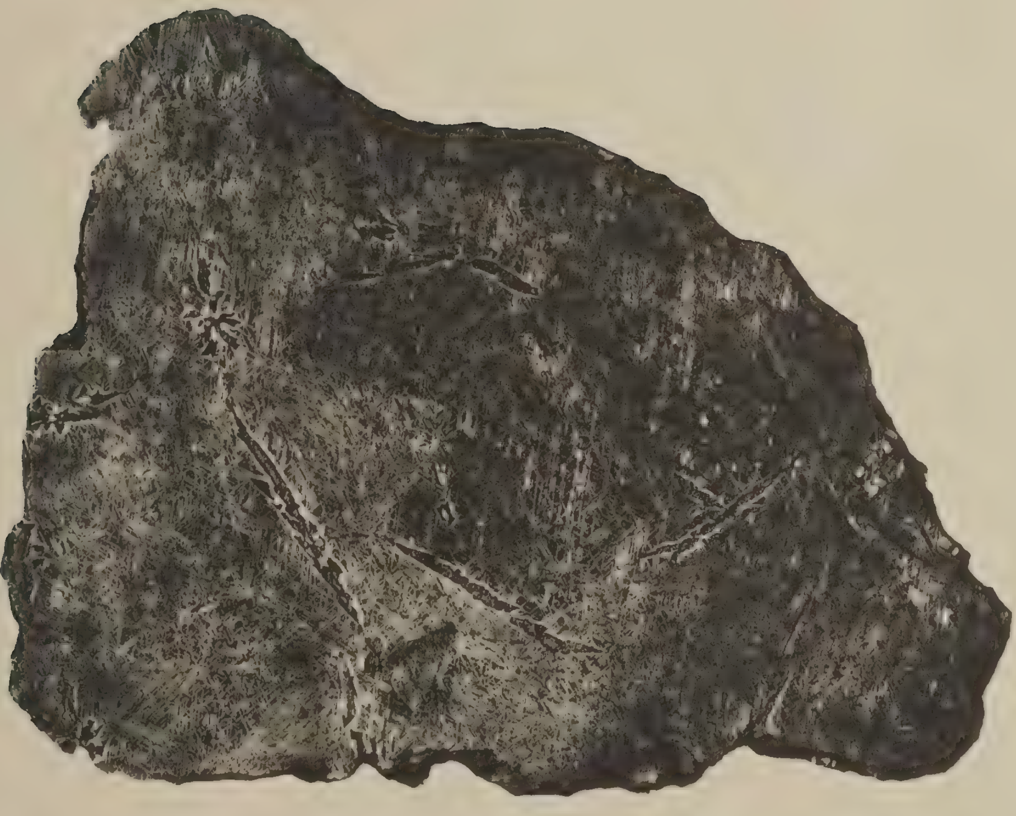


FIG. 2. Hamilton Co., Texas.

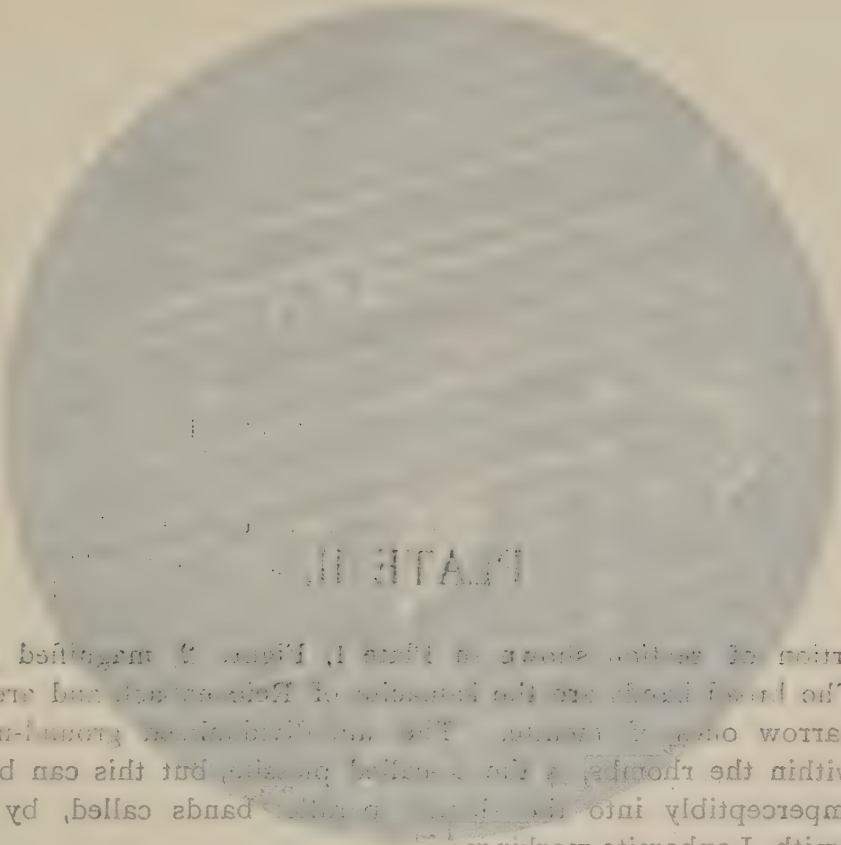


Fig. 2. Hamilton Co., Texas.

PLATE II.

Fig. 1. Portion of section shown in Plate I, Figure 2, magnified 14 diameters. The broad bands are the kamacite of Reichenbach and are bordered by narrow ones of taenite. The unindividualized ground-mass enclosed within the rhombs, is the so-called plessite, but this can be seen to pass imperceptibly into the slender parallel bands called, by J. Lawrence Smith, Laphamite markings.

Fig. 2. Another portion of the same section magnified 14 diameters. The etching figures are similar to those shown in Fig. 1, and there is also shown an inclusion of troilite, bordered by a layer of kamacite.

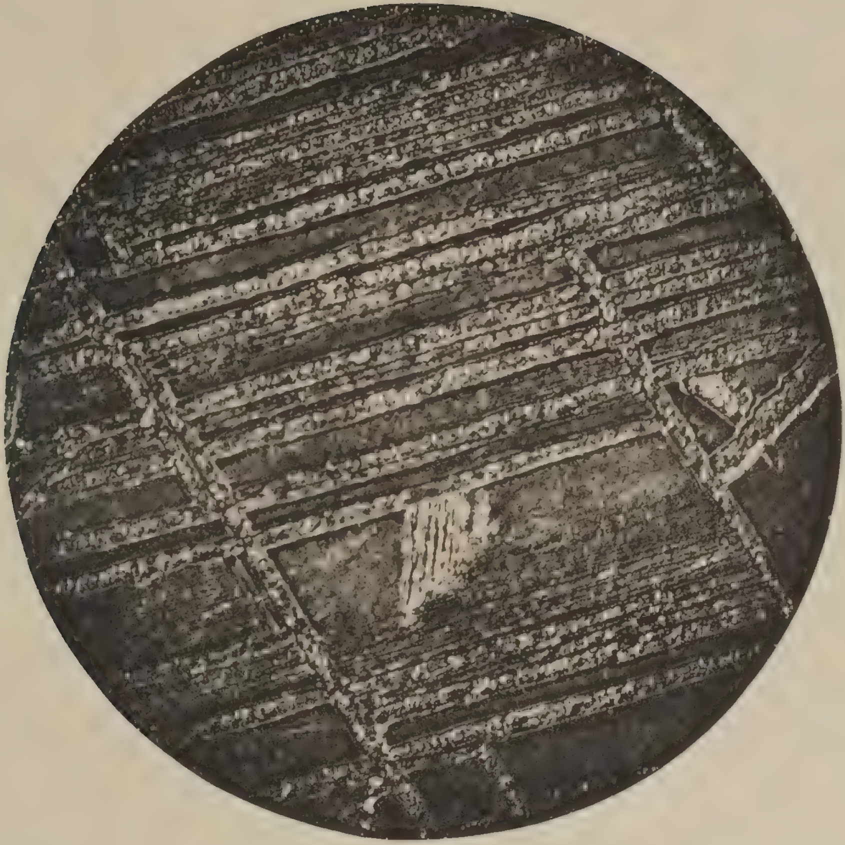


FIG. 1.

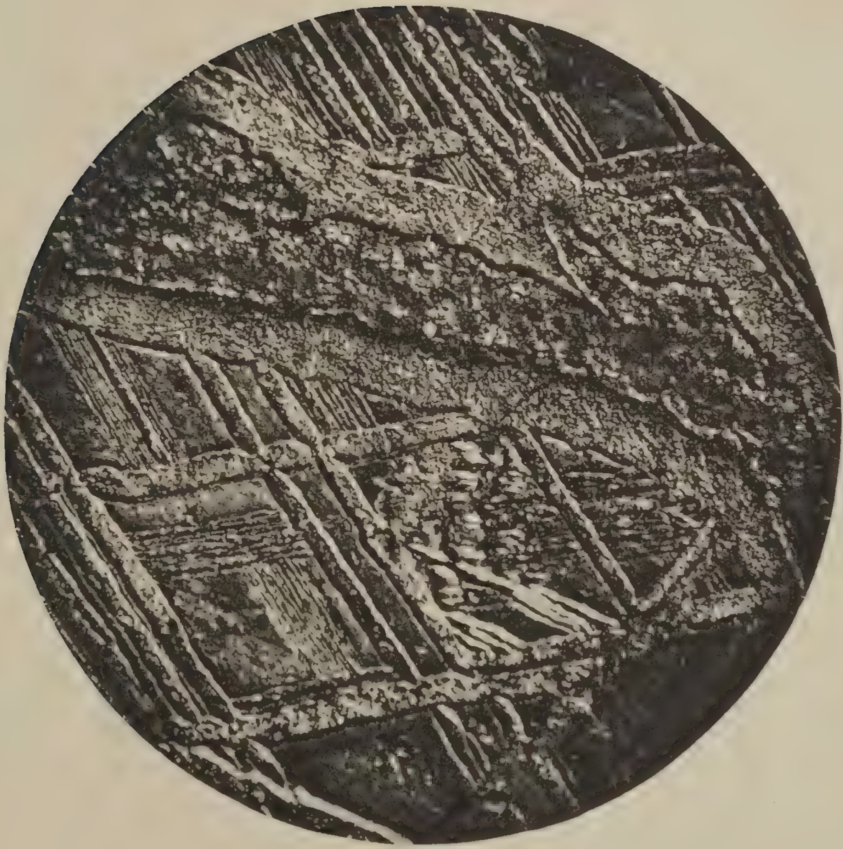


FIG. 2. Hamilton Co., Texas.

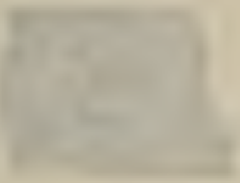


FIG. 1. Laurens Co., S. C.

FIG. 2. Lion River, S. Africa.

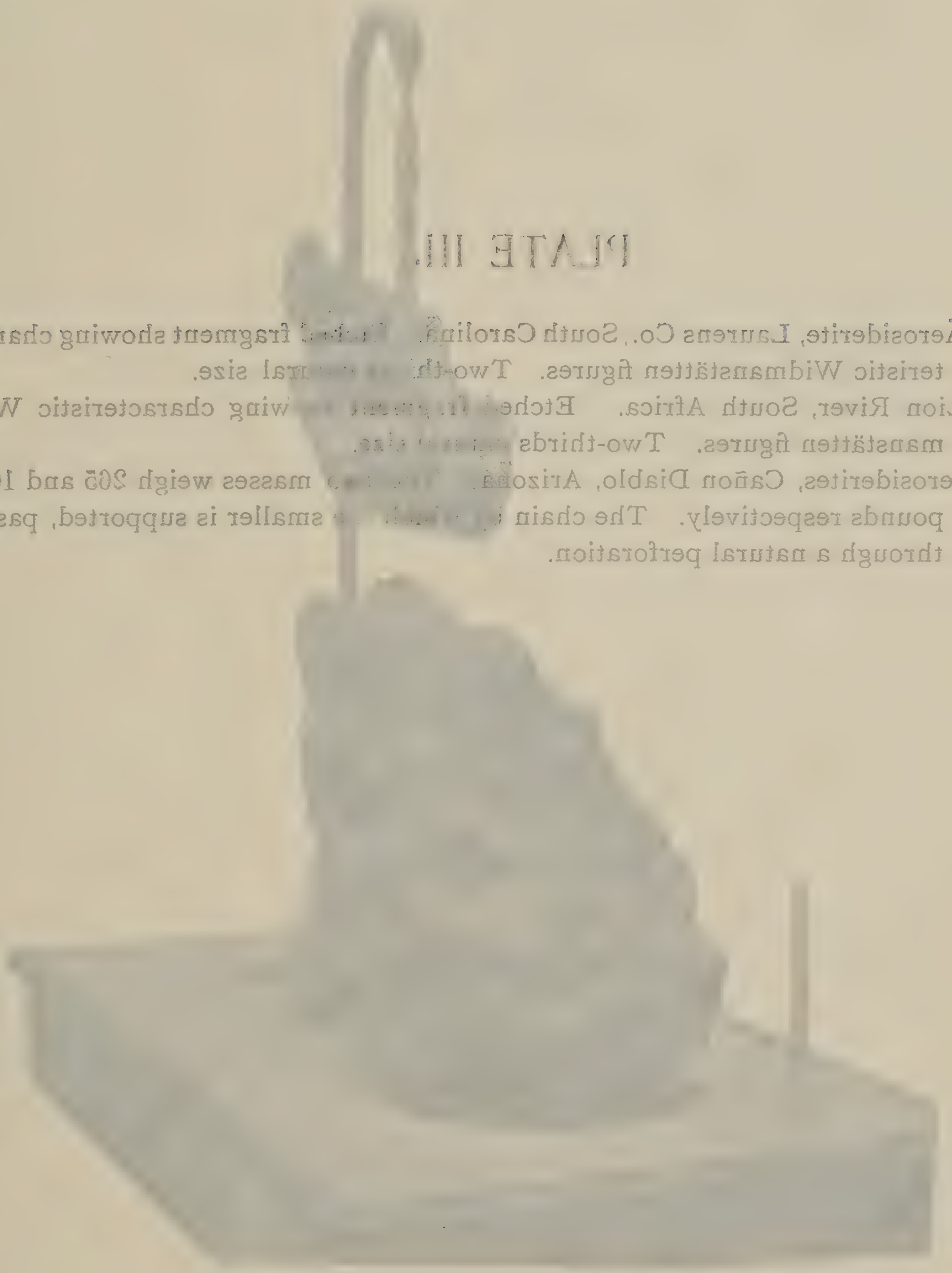


FIG. 3. Cañon Diablo, Arizona.

PLATE III.

Fig. 1. Äerosiderite, Laurens Co., South Carolina. Etched fragment showing characteristic Widmanstätten figures. Two-thirds natural size.

Fig. 2. Lion River, South Africa. Etched fragment showing characteristic Widmanstätten figures. Two-thirds natural size.

Fig. 3. Äerosiderites, Cañon Diablo, Arizona. The two masses weigh 265 and 1013 pounds respectively. The chain by which the smaller is supported, passes through a natural perforation.

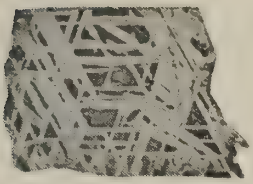


Fig. 1. Laurens Co., S. C.

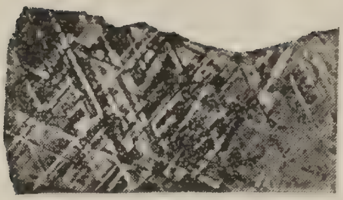


Fig. 2. Lion River, S. Africa.

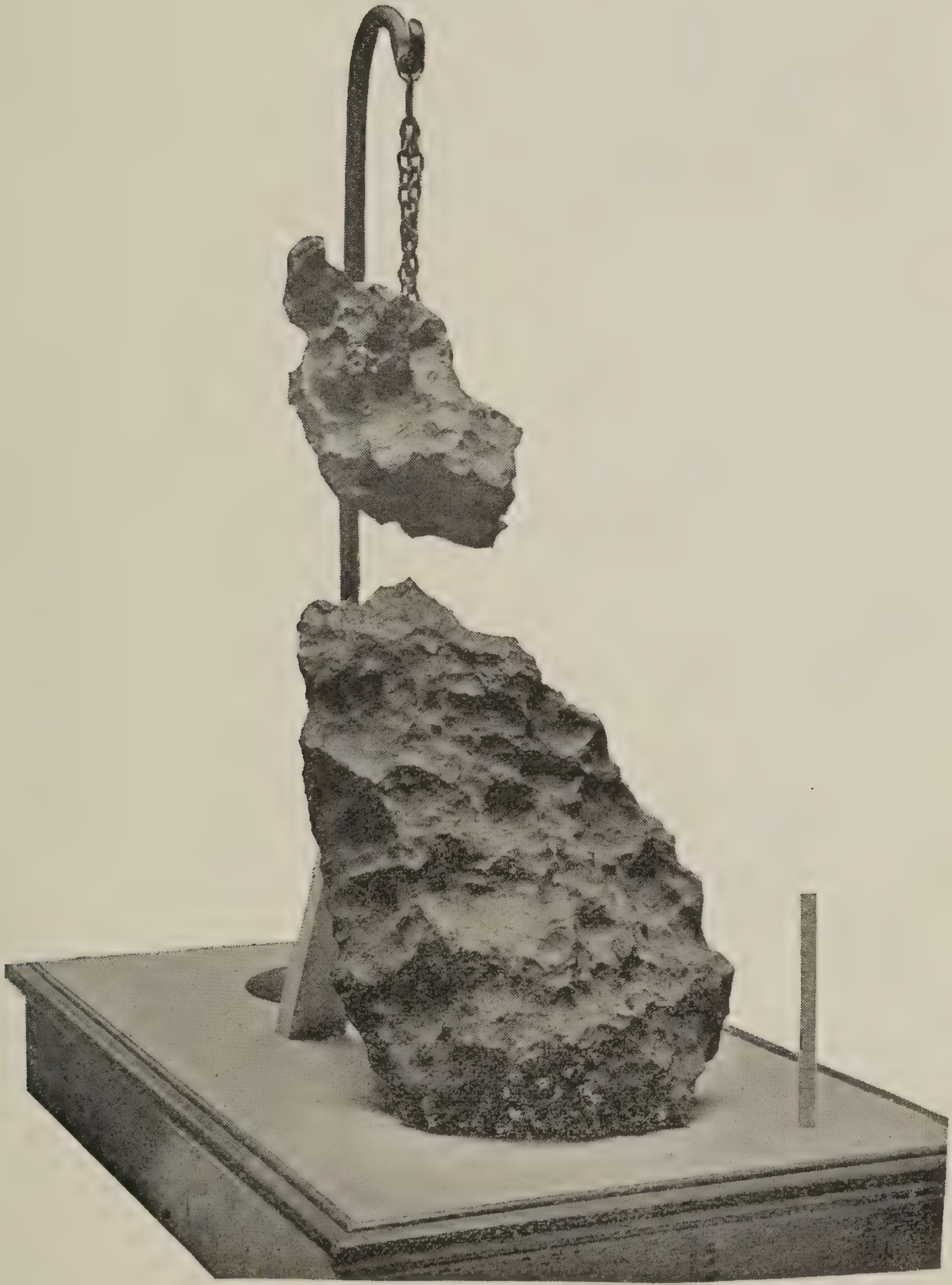
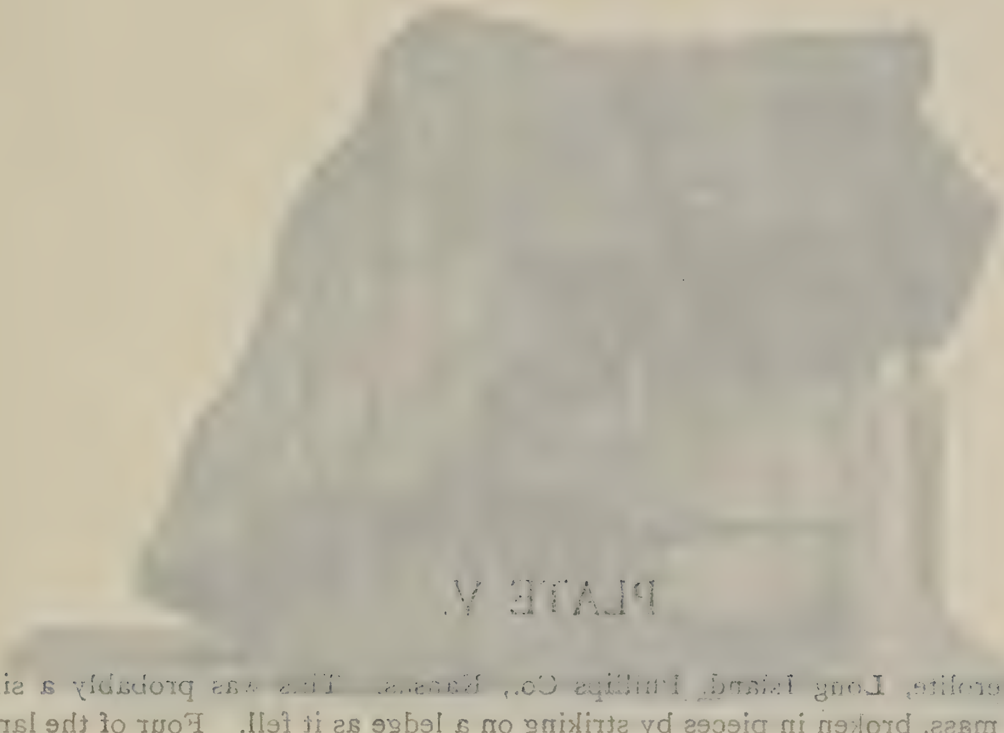


Fig. 3. Cañon Diablo, Arizona.



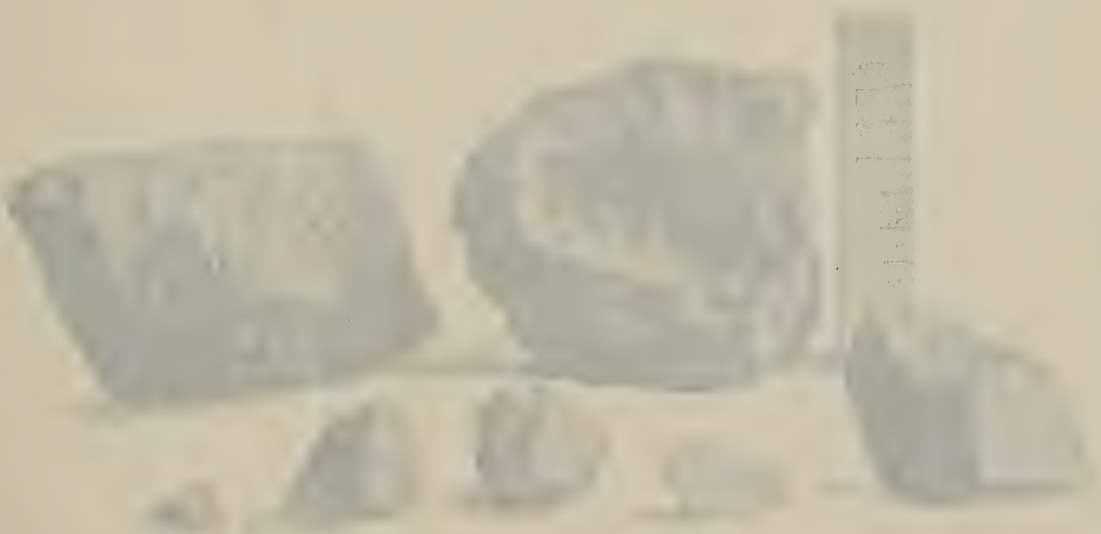


FIG. 2. Leland, Winnebago Co., Iowa.

PLATE V.

Fig. 1. Äerolite, Long Island, Phillips Co., Kansas. This was probably a single mass, broken in pieces by striking on a ledge as it fell. Four of the largest of the fragments have been joined together along the planes of original fracture, giving the mass shown in the figure. The other fragments occupied the place of the pedestal. The white coating shown over a portion of the surface was undoubtedly formed subsequent to the fall of the stone. The true crust has the appearance of an earthenware glaze.

Fig. 2. Seven individual äerolites, Leland, Winnebago Co., Iowa, showing crust, pitted surface and interior.

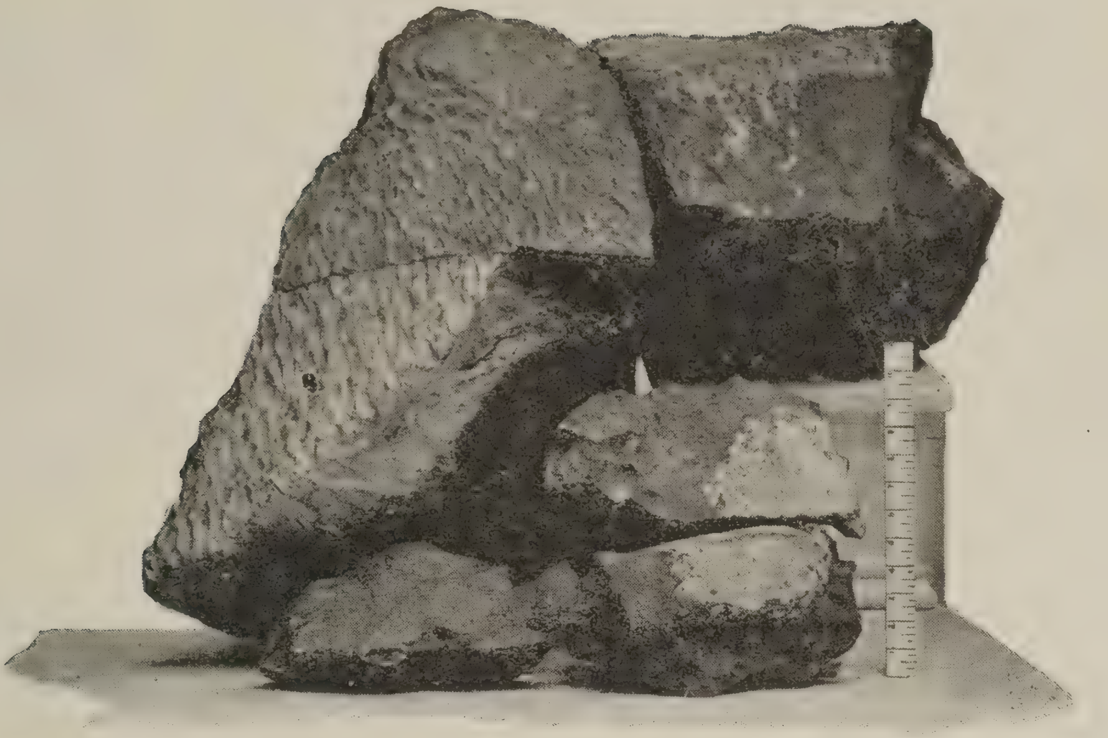


FIG. 1. Long Island, Phillips Co., Kansas.

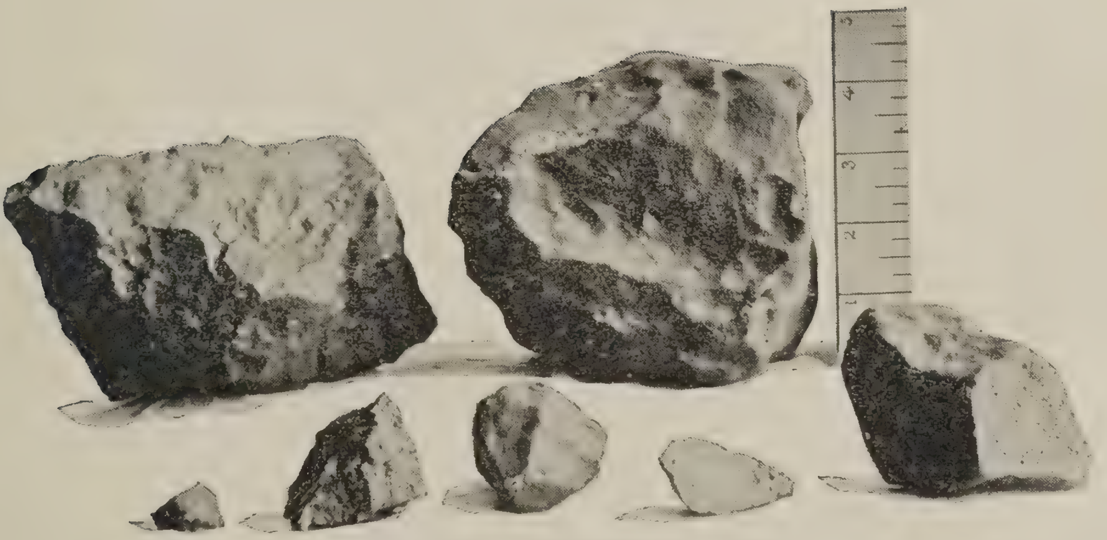


FIG. 2. Leland, Winnebago Co., Iowa.

LIBRARY
OF THE
UNIVERSITY of ILLINOIS.

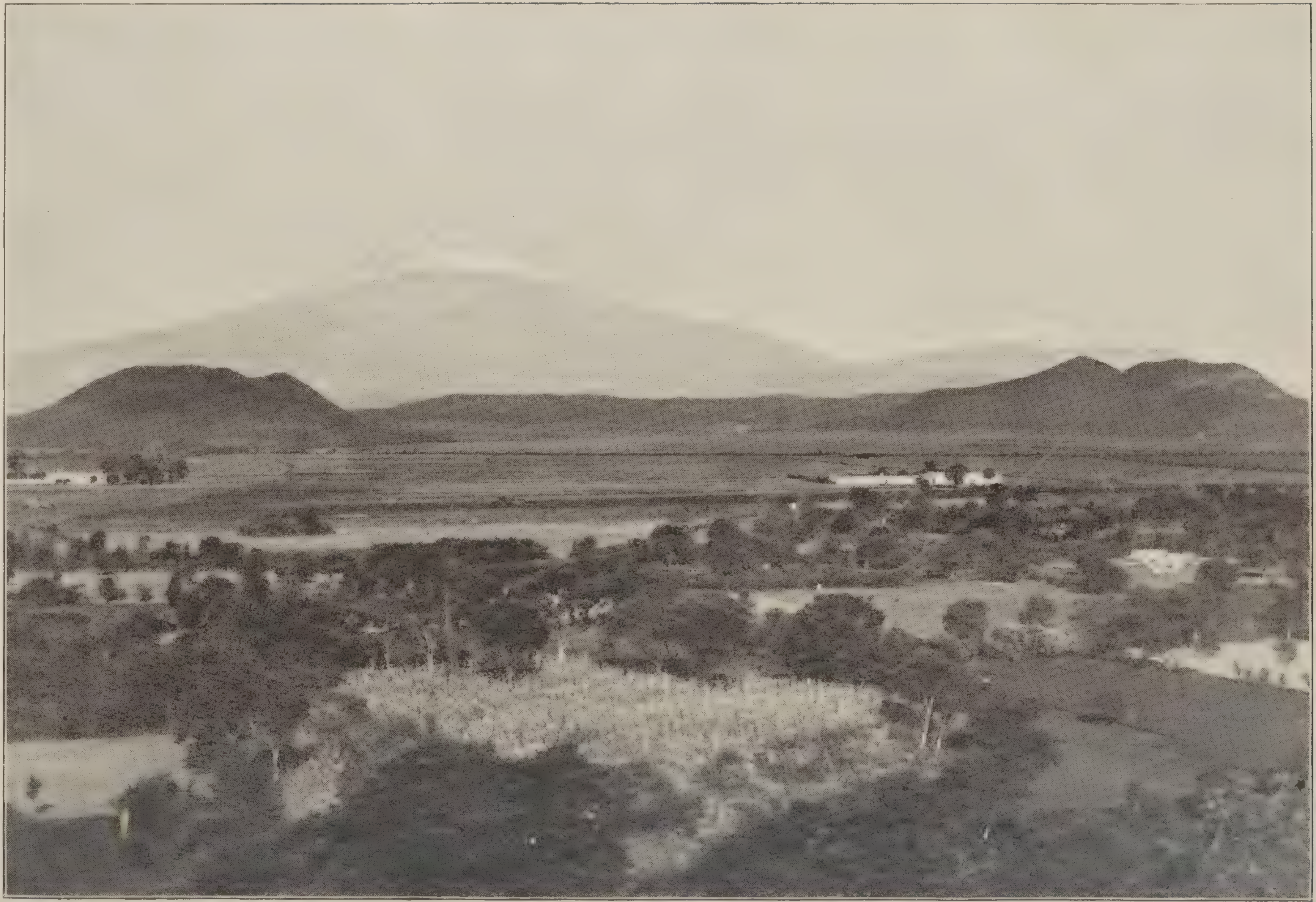


Photo. by Briquet.

POPOCATEPETL AND IXTACCIHUATL FROM THE VALLEY OF PUEBLA.

FIELD COLUMBIAN MUSEUM

PUBLICATION 18.

Geological Series. Vol. 1, No. 2.

OBSERVATIONS ON POPOCATEPETL AND IXTACCIHUATL

WITH A REVIEW OF THE GEOGRAPHIC AND GEOLOGIC FEATURES OF THE MOUNTAINS.

BY

OLIVER C. FARRINGTON, PH.D.,
Curator, Department of Geology.

CHICAGO, U. S. A.
April, 1897.

TABLE OF CONTENTS.

Page.

Preface 71

Bibliography 73

The Sierra de Ahualco 75

Route to the Mountains 77

Popocatepetl 80

El Pico del Fraile 99

Petrography 100

Ixtaccihuatl 103

Porfirio Diaz Glacier 111

Petrography 119

LIST OF ILLUSTRATIONS.

Plate.		Opposite page.
VII.	Popocatepetl and Ixtaccihuatl from the Valley of Puebla .... (Frontispiece)	
VIII.	El Pedregal, near San Angel	76
IX.	Popocatepetl from Ameca	80
X.	Upper Cone of Popocatepetl	92
XI.	Crater of Popocatepetl	94
XII.	Eastern Wall of Crater	96
XIII.	Ixtaccihuatl from Ameca	103
XIV.	Middle and Southern Peaks of Ixtaccihuatl showing Porfirio Diaz Glacier	110
XV.	Porfirio Diaz Glacier from old terminal Moraine	112
XVI.	Surface of Porfirio Diaz Glacier	114
XVII.	Old Moraines, Porfirio Diaz Glacier	116
XVIII.	Contour map of Popocatepetl, Ixtaccihuatl and vicinity	122

Fig.		Page.
1.	The Ranch of Tlamacas	89
2.	Gathering of Bowlders by a Crevasse	114

PREFACE.

No two mountains of the Western Hemisphere have been perhaps longer or more widely known than those treated of in the following pages. First brought into notice in 1519 by Cortes during his conquest of Mexico, they have been more or less identified with many subsequent events, not only of Mexican but also of our own history. This is largely for the reason that the pass between them has furnished the route by which American as well as Spanish and French invaders have marched to the beautiful Capital.

Tourists and travelers have for centuries been drawn to them too, on account of the majestic and striking appearance which they present as seen from the City of Mexico, to whose scenic charms they lend an imposing and beautiful background.

Popocatepetl has, moreover, to many generations of school children, been known as a volcano usually mentioned by their geographies, which had a name so formidable that it stuck in their memories, like a burr, after less prickly terms had disappeared. Yet, in spite of the long-continued interest to which these mountains may lay claim, any detailed account in English of their history or geology is hard to find. Spanish and German explorers have described them in more detail, but with the exception of Sonntag, few English writers have sought to give any scientific description of them. This fact tempts one to quote the remark of a distinguished geographer, that "the English are the first to explore but the last to describe."

My own opportunity for observing the features of these mountains was indeed brief, so brief that were wider knowledge of them extant I might well hesitate to give my own observations publication. At the same time impressions were gained which deserve some weight when taken in connection with the opinions of other observers; experience valuable for further work was obtained, and the opportunity afforded to study somewhat more in detail than other observers have done the glacier on Ixtaccihuatl enables me to add something to the meager fund of knowledge possessed in regard to tropical glaciers. Deeming my own observations, therefore, not unworthy of publication, I have thought that to join with them a résumé of what other observers, chiefly Spanish and German, had noted, would put the present state of knowledge concerning the mountains in a form more accessible to English readers, would afford a means of stating the problems yet unsolved in regard to the structure and geology of the mountains and would aid travelers from our own country in making additional observations as opportunity afforded. The performance of this latter part of my task I have not been able to carry out in as comprehensive a manner as I wished, owing to inability to consult all the literature. The principal works, however, were at command.

For courtesies shown, and assistance in my trip, I am indebted to many, but among these should be mentioned President E. E. Ayer, of the Field Columbian Museum; President A. A. Robinson, of the Mexican Central Railway; Mr. W. W. Blake, of the *Two Republics;* General Sanchez del Ochoa, of the City of Mexico, and Señor Don Pedro de la Noriega, of Ameca.

BIBLIOGRAPHY.

A list of works referred to in the text, as well as of other papers devoted especially to the subject of this publication, is here given. Those marked with an asterisk I have not been able to consult directly:

Aguilera, Jose G. and Ordoñez, Ezequiel. Expedicion cientifica al Popocatepetl. Mexico, 1895.

Baker, Frank C. A Naturalist in Mexico. Chicago, 1895.

**Boletin* de la Sociedad Mexicana de Geografia y Estadistica, Boletin VI, Mexico. Since 1850.

Felix, J. and Lenk, H. Beitrage zur Geologie und Paleontologie der Republik Mexico. I Theil, Leipzig, 1890. II Theil, I Heft, Leipzig, 1893. III Theil, Stuttgart, 1891.

Heilprin, Angelo. Barometric Observations among the High Volcanoes of Mexico, with a consideration of the culminating point of the North American Continent. Proc. Acad. Nat. Sci. of Philadelphia, 1890. Philadelphia, 1891.

Howarth, O. H. Popocatepetl and the Volcanoes of the Valley of Mexico. The Geographical Journal, Vol. VIII, No. 2, p. 137. London, 1896.

Humboldt, A. Essai Politique sur le Royaume de la Nouvelle Espagne. Paris, 1826.

Ober, Frederick A. Travels in Mexico. Boston, 1887.

Packard, A. S. Ascent of the Volcano of Popocatepetl. Am. Nat., Feb., 1886. Philadelphia.

Pieschel, C. Die Vulcane von Mexico. Zeitschr f. allg. Erdkunde. Bund. V, pp. 170 and 190. Berlin, 1885.

Sonntag, A. Observations on Terrestial Magnetism in Mexico, with notes and illustrations of an examination of the Volcano of Popocatepetl and its vicinity. Smithsonian Contributions to Knowledge, Vol. XI. Washington, 1859.

**Whitehouse, H. Remise.* Alpine Journal, Vol. XV. Nov., 1890.

THE SIERRA DE AHUALCO.

Popocatepetl and Ixtaccihuatl are the highest peaks of a mountain range or Sierra about 60 miles in length, and 18 in breadth, which extends in a general north and south direction from Jonacatepec in the State of Morelos to Otumba in the State of Hidalgo. This Sierra is called the Sierra Nevada or snowy Sierra of Ahualco. Its extent in latitude is from 18° 55′ to 19° 47′ N. Lat. The Sierra is, therefore, well within the tropics. Its longitude is from 98° 53′ 15″ to 98° 55′ W. from Greenwich. It is 35 to 50 miles east of the City of Mexico. Other important peaks of the ridge, all lying to the north, are Tlaloc, Telapon and Papayo. Rising out of the plains of Apam to the north, the Sierra gradually increases in height until it culminates in the cone of Popocatepetl at its southern extremity. Its average height above the plateau on which it stands is 5,000 feet and above the level of the sea 13,000 feet. From the culminating point at the south the Sierra descends sharply to the plateau, which itself then falls off rapidly—in many places abruptly—several thousand feet.

The Sierra constitutes a barrier which separates the valley of Puebla on the east, from the valley of Mexico on the west; the shortest line of communication between the two valleys is a saddle-shaped pass between Popocatepetl and Ixtaccihuatl, whose lowest point has a height of 12,118 feet.

The Sierra also determines the flow of the waters into these valleys. Thus the waters descending the western slopes of the ridge flow into Lakes Texcoco and Chalco, of the valley of Mexico, and those of the eastern slopes into the plains of Apam and the river Atoyac, which skirts the southern end of the ridge, and empties into the Pacific Ocean.

While the ridge constitutes a topographic unit, viewed as a volcanic series it is made up, in the opinion of Felix and Lenk,* of two elements; the first, Popocatepetl, is situated on the line of a great fissure running east and west, with which are connected the volcanoes Ajusco, Toluca, Patzcuaro and others; the second, Ixtaccihuatl and the peaks of Telapon and Tlamacas, stands upon a line of side fracturing nearly at right angles to the former. Popocatepetl may, however, properly be considered as situated at the junction of the two lines of fissures, a fact which may account for its superior size and activity.

---

*Beitrage zur Geologie und Paleontologie der Republik Mexico, I Theil, p. 6.

The time at which the eruptions took place by which this great volcanic series was formed is regarded by the same authors as the close of the Mesozoic. This estimate is based on the entire absence of remains of Tertiary age in the strata of the region. Cretaceous fossils are found in greater or less abundance, and following these, remains of Pliocene mammals, but no relics of life of intermediate age occur. It may therefore be inferred, they conclude, that the close of the Mesozoic was marked by volcanic activity so widespread and long-continued, that life could not exist in the region, nor could it again find habitation there until stable conditions were re-established. If it is correct to assume that these eruptions took place at the close of the Mesozoic, they were contemporaneous with the upturning of the Rocky Mountains and the great igneous eruptions of Wyoming and Montana.

Other authors, however, regard the volcanoes as of Miocene origin, making them contemporaneous with the volcanoes of the Pacific Coast region.*

At whatever time the volcanic activity had its beginning or reached its maximum, it was long-continued, and some traces of it yet exist. Not only is Popocatepetl in a state of partial activity, but also in the valley of Mexico in the soil underlying some of the lava outflows, notably one near San Angel which came from the volcano of Xitli, are found human bones and fragments of pottery, which prove that man was living at the time the outflow occurred. (See Pl. VIII.)

The rock of this outflow is a plagioclase basalt, now quarried for paving.

Following the cessation of volcanic activity came a change of climate characterized by greater precipitation. The lava flows and volcanic debris dammed up sections of the country to form great basins which became filled with water, and formed numerous and extensive lakes. About these lakes wandered large mammals of various species, whose remains are more or less frequently found in the lacustrine deposits of the valleys.

Already are known species of camel, bison, llama, elephant and horse from the beds of the region, and two nearly complete skeletons of glyptodon (armadillo) have been obtained. The former greater

---

*Dana, Manual of Geology, 4th Ed., p. 937.

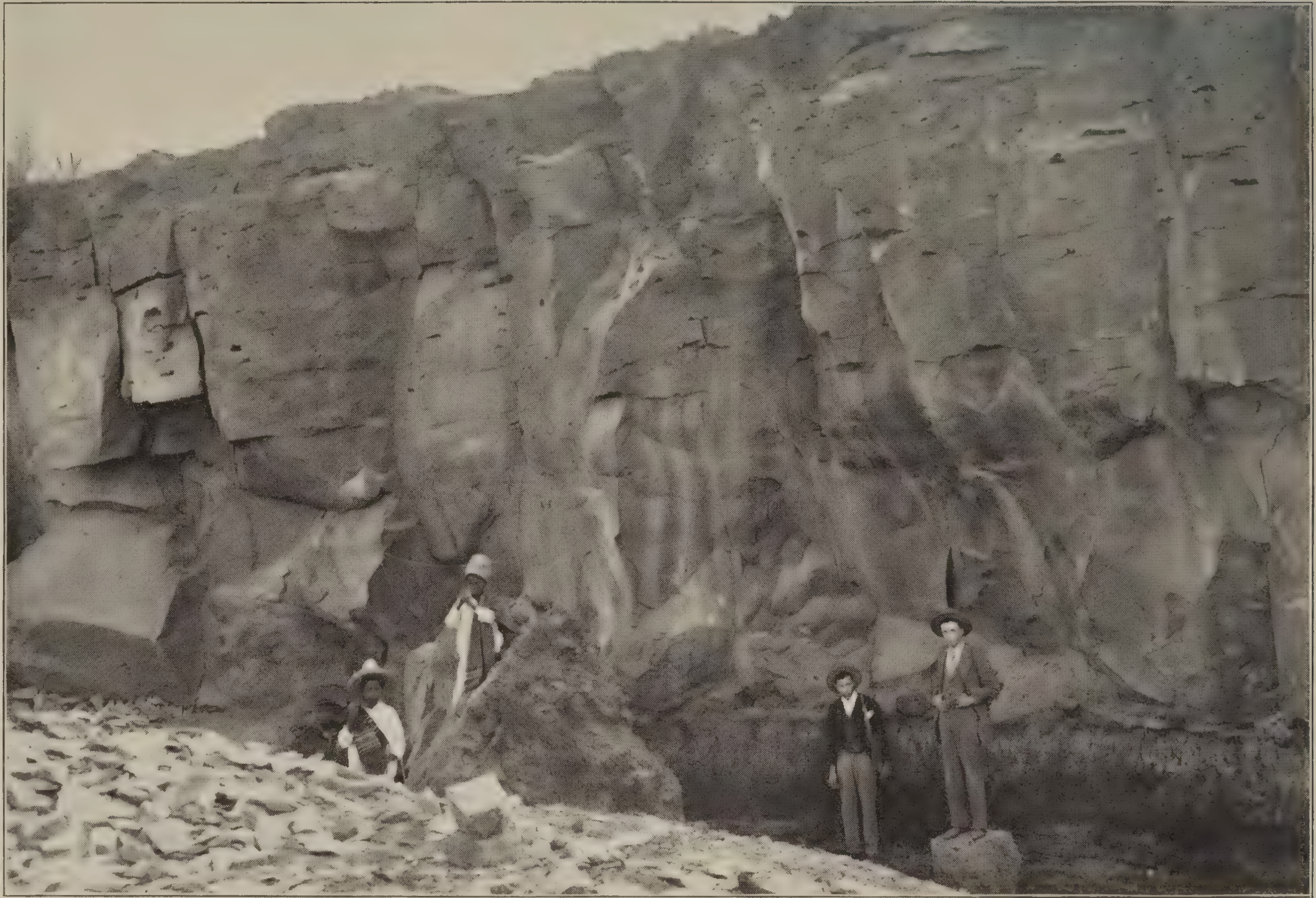


Photo. by the Author. SECTION OF LAVA FLOW AT EL PEDREGAL, NEAR SAN ANGEL, VALLEY OF MEXICO.

The rock rests on soil in which human bones and implements have been discovered; the heat from the flow oxidized the soil to a red color. The section shows the vesiculation of the lava by escaping vapor bubbles; towards the upper surface the vesicles are larger on account of diminished pressure.

extent and number of these lakes, of which such modern ones as Texcoco and Chalco are but shrunken remnants, is shown by lacustrine deposits found on the slopes of the mountains, and by plains, such as the plain of Ameca, which were once lake beds but are now dry.

In the view of Packard there was also a glaciation of the entire region, presumably at the time of the Glacial Period, but of this extensive glaciation I was myself unable to find further evidence.

ROUTE TO THE MOUNTAINS.

The starting point usually chosen from which to make an ascent of either of the two principal peaks of the Sierra is Amecameca or, as it is commonly known at the present time, Ameca. It is a city of about 12,000 inhabitants, situated nearly forty miles by rail south-east of the City of Mexico.

It is reached by the Morelos division of the Inter-oceanic Railway, the ride from the City of Mexico occupying about two hours. The road passes out first over the level expanse of a plain formerly included in Lake Texcoco, the water of which may be seen to the east. A few miles further on the cones of a number of extinct craters can be seen on either side of the way. These belong to the range of the Santa Catarina volcanoes on the west, while the cone of El Pino lies to the east. These are all minor eruptive cones of comparatively recent formation, and consist, together with brecciated and scoriaceous materials, chiefly of hypersthene-andesite, a rock corresponding to that of the later flows of Popocatepetl.

The road then skirts the shore of Lake Chalco, the extent of water in which varies greatly with the season. From here the ascent is rapid, the road winding about in huge curves, to gain the higher plain of Ameca. To the east rises the peak of Tenayotl, a hill of hypersthene-andesite, its slopes clothed with forests of pine. Behind it stands the snow-crowned Sierra. To the west are the craters and cones of the group of volcanoes of which Ajusco is chief—a barren and desolate range. The slopes of many of these cones are unusually steep and their shape typically volcanic. The rock of which they are composed is basalt, so that volcanoes closely associated in time and space poured forth the one an acidic, the other a basic lava.

All along the route frequent views of Ixtaccihuatl and Popocatepetl may be gained, though their summits are much of the time hidden by clouds. These clouds are, during the dry season, of the cumulus type, and frequently invest the summits of the mountains when the rest of the sky is clear, indicating that the chilling of the moisture of the air by the cold of the summits has formed them. This is further indicated by the way in which they can be seen to gather and roll down the mountain slopes. They usually lie at about the height of the snow line on the mountains, 13,000 feet above the sea, but under other conditions of the atmosphere frequently descend lower.

Ameca is on the western side of the Sierra, standing upon a level plain, once, probably, as has been said, the bed of a lake, now at a height of 8,132 feet above the level of the sea. Near the western edge of the plain rises a dome-like hill about 400 feet in height clothed with beautiful pines and cedars. This is called the Sacromonte or sacred hill. Upon it stand two ancient churches, one of which contains an image of Christ of especial interest to the devout Catholics of Mexico. For this reason thousands of pilgrims come to Ameca during each year, from all over Mexico, to worship at its shrines. Moreover, the natural beauty of the spot, and its cool, delightful climate make it an attractive resort for picnic parties, who do not fail to improve the opportunities the town affords for rest and refreshing. There is an excellent hotel in the town where good food and lodging can be obtained, as well as provisions for a trip to the mountains.

Horses and guides can also be procured in the town, from Sr. Don Pedro de la Noriega, a young and enterprising Mexican, proprietor of one of the largest *tiendas* or stores, and agent for the owner of the sulphur mines. By informing him in advance, guides and horses can be had in readiness to meet parties on the arrival of the morning train, and thus the ascent to the snow line can be accomplished the first day. For the ascent of Popocatepetl permission should be obtained from General Sanchez del Ochoa, the owner of the sulphur mines, now residing in the City of Mexico, in order to camp at the so-called Ranch of Tlamacas. A letter of introduction from him to Sr. Don Pedro de la Noriega will also be of assistance in securing prompt and obliging service. If one does not speak the Spanish language, a companion should by all means be obtained who can act as interpreter, for none of the residents of Ameca speak English, and the resources of sign language are quite inadequate for so arduous an undertaking as the ascent of one of these mountains.

The expenses of the trip will of course vary with the number in the party, but are proportionately smaller the larger the number.

The average price for a mounted guide is $3 per day, Mexican money,* for foot guides or *peons* $1.50, for a saddle horse $2, and a pack mule $1. One of each of these is needed for an ascent by a single person, but for a larger number only one or two foot guides need be taken. If it is desired to descend to the bottom of the crater, though, five or six *peons* or Indian servants must be taken to work the windlass. There are also a few other sundries to be reckoned, such as leather for sandals, cloth for wrapping the feet and colored glasses, but these are only small items.

A partial ascent of either of the mountains can well be made for the sake only of the magnificent views and charming scenery to be gained. The complete ascent is, however, a more serious matter and should never be undertaken by persons not in vigorous health, or by any one having any weakness of the heart or lungs.

---

*One dollar in Mexican money equals 54 cents United States currency at the present rate of exchange.

POPOCATEPETL.

Popocatepetl, the smoking mountain, its name being derived from the Aztec words *popoca*, smoking, and *tepetl*, mountain, is a volcano taking rank by its altitude among the highest mountains of North America.

While its altitude is so great that it has often been regarded the highest peak on the continent, the most recent determinations assign to it the fourth place. Mt. Logan, situated in Lat. 60° 34′ N., and Long. 140° 24′ W., according to recent determinations by the United States Coast and Geodetic Survey, is the highest, having an altitude of 19,539 feet; Mt. St. Elias comes next, with an altitude, according to the same Survey, of 18,024 feet; Orizaba in Mexico, third, with a height according to Ferrer, of 17,879 feet, while the fourth is Popocatepetl with a height, by Sonntag's measurement, of 17,784 feet.

Seen from the west, or side upon which Ameca is located, Popocatepetl presents the appearance of a symmetrical, rounded, snow-capped cone rising about 5,000 feet above the ridge of the Sierra on which it stands. The average slope of this cone is about 30 degrees, though it appears much steeper to the eye.* Seen from the south, or valley of Puebla, the volcano presents a more imposing aspect (See Frontispiece) for here its massive cone rises uninterruptedly for 13,000 feet out of a valley luxuriant with semi-tropical foliage. Its lower slopes are clothed with groves of deciduous trees and firs, and above these is a zone of conifers, chiefly pines. The remainder of the cone is black and naked except for a mantle of snow of varying length, which sometimes disappears altogether from the eastern and southern slopes.

This disappearance of the snow is undoubtedly due to the warm airs which rise from the valleys of Puebla and Cuautla and not to the cause suggested by Heilprin†—that of the vapors which flow out from the lip of the crater. These are too limited in quantity to have any appreciable heating effect.

The summit of the cone is truncated obliquely by the crater, whose walls are highest on the west and lowest on the east,‡ so that

---

*The author, Science, New Series, Vol. IV, No. 87, p. 271.

†The Geographical Journal, Jan. 1897, p. 100.

‡See p. 94.

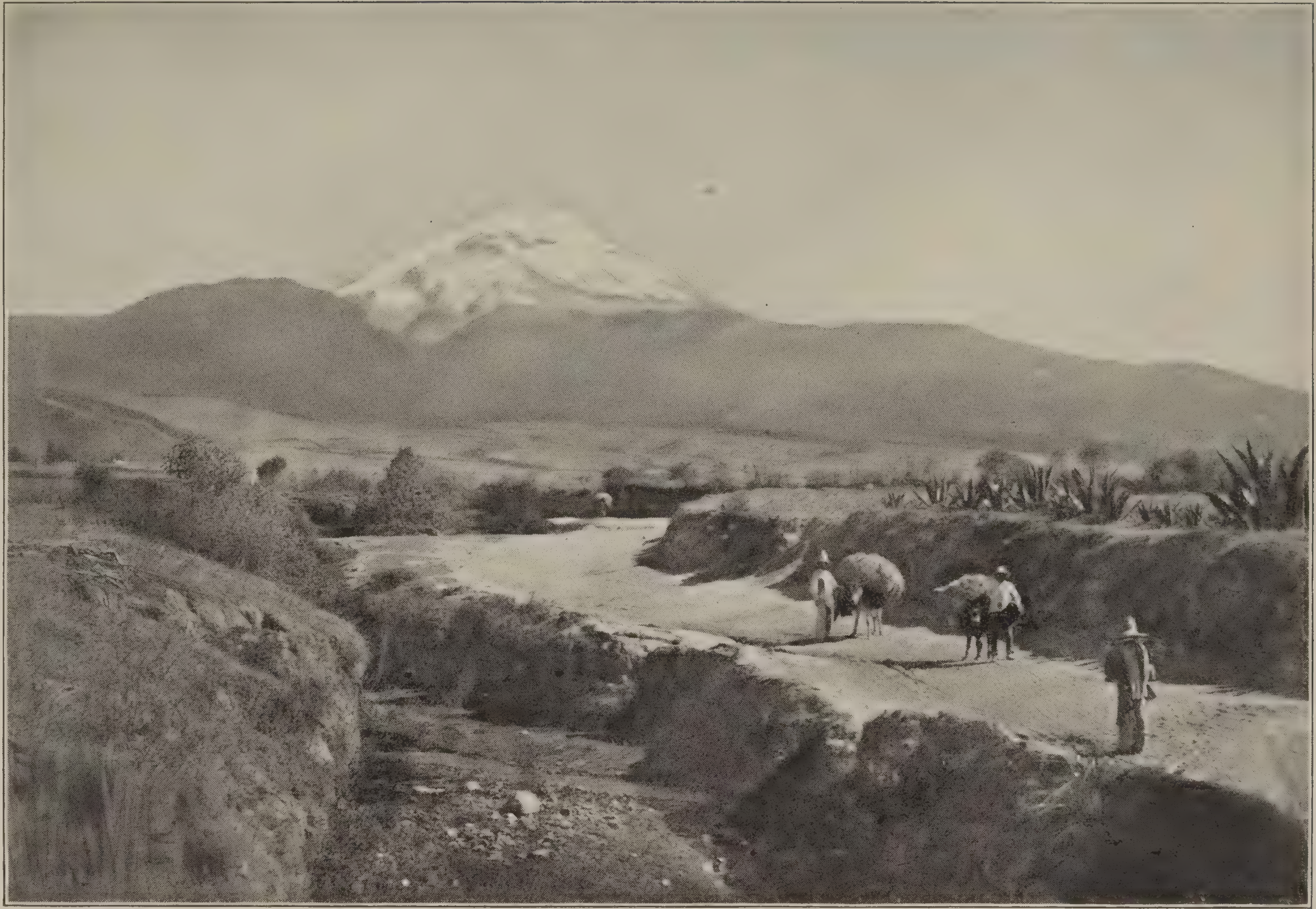


Photo. by Briquet.

POPOCATEPETL FROM AMECA

from the valley of Puebla in favorable weather the western wall of the crater may be seen as a thin, black streak standing above the snow-mantled eastern slope.

When approached nearer the apparent regularity of the cone disappears, for while the upper portion, clothed with sand and snow, presents a nearly uniform slope, into the middle portion descending waters have cut numerous channels, and the lower portion is involved in the tortuous folds which make up the Sierra. On the northwestern slope, too, the sharp, jagged peak known as the Pico del Fraile rises to a height only about 1,000 feet less than that of the principal cone, and cutting an amphitheater-like section out of the mountain destroys its symmetry.

Popocatepetl belongs to the class of volcanoes known as stratified, because of the resemblance to sedimentary formations which is presented by the successive layers of lava of which it is made up.

In the character of the lava of these successive outflows Aguilera and Ordoñez* have traced a marked gradation corresponding to a gradual decrease in the heat and energy of the volcano. Thus the lavas of the lower currents they assert to be granular, devitrified and of trachytic structure, while those of the upper are vitreous and amorphous, with, however, a few phenocrysts.

This difference in structure they explain on the ground that the upper currents being farther from the source of heat were more nearly cooled when poured out and thus became solid before time sufficed for crystallization. A difference in mineralogical composition of these lavas is also noted. Those of the lower areas are basalts containing a large amount of olivine; those of the upper, hypersthene-andesites. These authors also believe that three periods in the life of the volcano, marked by the character of its products, can be distinguished and that these correspond with a gradual diminution in its heat and energy. These periods they characterize as the period of lava eruptions, of breccia eruptions and of ash eruptions respectively.

This view has been justly criticised by a reviewer † as presuming conditions so extraordinary as to be hardly probable. It is far more likely that the change in products from lavas to breccias and breccias to ashes has been many times repeated in the life of the volcano.

The activity of the volcano in modern times has been confined to the emission of steam and sulphur from the crater. It is, in other words, in a state of solfatara activity, which seems itself to be gradually disappearing.

---

*Expedicion cientifica al Popocatepetl, p. 23.

†Neues Jahrbuch, II Bd., Thiel III, p. 270, Stuttgart, 1896.

If the accounts of the early Spanish conquerors are to be believed, at the time of their arrival, in 1519, the volcano was in a state of violent activity, and emitted clouds of smoke (steam) and at intervals showers of stones and ashes. This activity continued until 1523, when a period of rest intervened and then in 1539 a small eruption of stones and ashes took place. After this no further eruption occurred till near the close of June, 1664, when, for more than two days a shower of stones and ashes was sent forth. This seems to be the last eruption of which there is any knowledge, so that for more than two hundred years the volcano has been practically extinct.

The height, situation and partial activity of the volcano have combined to render it from the earliest times an object of great interest. Naturally the desire has been strong to ascend to its summit, and of these ascents and attempts at ascent many accounts exist.

The first inhabitants of the region, the Aztecs, were withheld, as we know, by superstitious fears from attempting to explore the mountain. They believed it to be an abode of evil spirits which no one could approach.* They therefore, were content to gaze upon it from a distance with awe and reverence. A round, artificial hill called Tetepetongo still to be seen near Ameca, was, according to the tradition, used by them as a place of sacrifice, and its location may indicate that some worship of the volcano was carried on here. Of this nothing is known, however.

It is to the bold Cortes that the credit of the first attempt at ascent of the volcano must be given. Marching with his little band in 1519 to the Capital of Montezuma his route led over the pass between Popocatepetl and Ixtaccihuatl. The volcano was at that time apparently in a state of much greater activity than to-day, and the curiosity of Cortes was aroused "to learn," as he says, "the secret of the smoke." Accordingly, one of his captains, Diego Ordaz by name, was sent with nine Spaniards and several natives to make the ascent. "Such an undertaking" says Prescott† "was eminently characteristic of the bold spirit of the cavalier of that day, who, not content with the dangers that lay in his path, seemed to court them from the mere Quixotic love of adventure." It is probable, too, that Cortes wished to impress the natives with a sense of his dauntless daring. Whether the bold captain Ordaz succeeded in his undertaking is not known. According to the account of his chief, he was, after enduring the greatest hardships and dangers and being deserted by part of his band, driven back when not far from the crater, by the blinding, suffocating volumes of smoke and cinders which belched forth from it, and was obliged to return, bringing as his only trophy some huge icicles, which were naturally objects of great curiosity to the natives. So great interest did the exploit arouse, however, that the Emperor, Charles the Fifth, learning of it, allowed the family of Ordaz to assume a burning mountain on their escutcheon, in recognition of Diego's bravery.

---

*Humboldt, Essai Politique, Vol. II, p. 673.

†Conquest of Mexico, Vol. II, p. 48.

In opposition to the account of Cortes, Bernal Diaz, generally a trustworthy historian of the Conquest, says that the attempt of Ordaz was made from Tlascala and was perfectly successful. Certainly, enough was learned of the crater, or of sulphur deposits somewhere, to lead to fitting out the next party which attempted the ascent with ropes and leathern sacks for procuring the same. This party was sent by Cortes in 1522 under Francisco Montaño to obtain sulphur for the making of gunpowder. If the accounts given by this party are to be believed, they reached the crater, and one of them being lowered into it, enough sulphur was procured to supply the wants of the army, though the expenditure of time and effort was such that Cortes reported to the Emperor that it would be more economical to bring powder from Spain. Humboldt* considers it quite impossible that either party should have reached the crater, and believes that the sulphur was procured from some lateral crevice, or possibly from the Pico del Fraile.

For a further account of the ascents of the mountain I can not do better than to translate from the excellent résumé given by Felix and Lenk.†

"In the same century" (the sixteenth), these authors state, "the learned Franciscan Monk, Bernadino de Sahagun, visited Popocatepetl, and Ixtaccihuatl as well. His whole description is limited to the statement 'I have been to the top,' an assertion so brief in contrast to the difficulty of the feat that it can hardly be taken as satisfactory evidence that he accomplished the ascent.

"Two centuries passed by without any further attempt, so far as known, to ascend the mountain. In 1770, however, Frederick Sonneschmidt, an intrepid German miner, who had lived for some time in Mexico, essayed the height. He succeeded in reaching only the Pico del Fraile, but was the first to make the mountain a subject of scientific investigation, and obtained a barometric measurement of the height of the latter peak.

---

* *Op. cit.* p. 164.

† *Op. cit.* pp. 17-20.

"In 1781 Antonio Alzate, the Mexican naturalist, again attempted the ascent, but reached only the snow line. Overcome and exhausted by the effort, he declared that to reach the summit of the mountain was simply impossible. This opinion, accordingly, was commonly held in Mexico for a long time thereafter, and probably aided in deterring Humboldt from attempting the ascent, as well as leading him to doubt the feats reported by Ordaz and his contemporaries. Humboldt did not himself ascend the mountain, but made his measurements of its height trigonometrically from the plain of Tetimba near Cholula.

"In 1827 two Englishmen, Messrs. F. and W. Glennie, with Mr. Taylor, undertook the ascent, and succeeded after much difficulty, on the 20th of April, in reaching the actual summit. They are, therefore, the first known to have scaled the height. Their ascent, it is interesting to note, was made on the southern slope of the mountain, which was at that time free from snow.

"In the same year a German, S. Birbeck by name, took barometric observations at the crater. His measurements indicate that he also reached the highest point of the mountain, but unfortunately, beyond his measurements of altitude, nothing is known further of the trip.

"On April 27, 1834, Baron Frederick von Gerolt, Baron L. Gros and Fl. Egerton, having previously failed on May 26th of the preceding year to get beyond the Pico del Fraile, succeeded in ascending to the crater. They obtained a measurement of the height of the Pico del Fraile, but were unable to make further observations on account of losing their barometers. One important result of their expedition was, however, the tidings of what had been known before, but apparently forgotten, the fact of the existence of large deposits of sulphur in the crater. It was not long after, therefore, before measures were taken to turn to practical advantage these somewhat inaccessible mineral treasures. In 1836, according to Laverriere, a resident of Ameca named Ignacio Reyes formed a plan to mine the sulphur. His plan was first put into execution in 1849 by a certain Juan Mugica, of Puebla, after a brave engineer, Antonio Garcia by name, had allowed himself to be lowered into the crater by a rope and had investigated the deposits. Mugica, through his administrador Perez, constructed at the crater's edge a windlass (*malacate*) for conveying the miners to and from the crater, and near the snow line on the mountain at the so-called Ranch of Tlamacas erected some rude buildings for refining the sulphur. The demand for the product seems at this time to have been very lively, for travelers visiting the mountains in the years following devote considerable space to a description of this peculiar industry, the pursuit of which at such a height is without a parallel on the globe.

"Feb. 27, 1851, two Frenchmen ascended the mountain, and to them Pieschel erroneously ascribes the first investigation of the sulphur deposits. The names of these men are not known. They seem to have made many scientific observations, and the description of the interior of the crater given by them is accurate and complete. In addition Pieschel gives some account of the ascent accomplished in January, 1853, by the Marquis de Radepont and the artist Pingret, as well as the one made by himself with companions on March 26 of the same year.

"In September, 1855, an expedition was made by Truqui and Craveri, which seems to have borne no results of value.

"In January, 1857, however, an expedition under commission from the Mexican government made an ascent which resulted in the most complete and accurate measurements of Popocatepetl that have yet been obtained. It was a well-organized, scientific commission, composed of the engineers, A. Sonntag, J. Laverriere, F. Sumichrast, Salazar and Ochoa. The union of trigonometric, barometric and thermometric observations, as carried on by this commission and reported by Laverriere and Sonntag, is so thorough and satisfactory that one is justified in giving the utmost confidence to the measurements obtained.

"The next scientific visitors to the mountain were the geologists of the French-Mexican Commission, viz.:—A. Dollfus, L. de Montserrat and Paul Pavie. They ascended the volcano April 23, 1865. They were not able to reach the highest peak, or Pico Mayor, on account of unfavorable weather, but their other measurements agree well with those of Sonntag. In 1882, members of the French Commission, sent to Puebla to observe the transit of Venus, ascended the mountain.

"A trigonometric measurement of the height was also made by Miguel Ponce de Leon in 1870 from the observatory of the School of Mines of the City of Mexico.

"Of late the ascent of Popocatepetl has become almost a fad of foreign travelers, but of those who attempt it not all succeed. Thus the widely experienced traveler, Gerhard von Rath, was obliged to give up the ascent a short distance from the summit in April, 1884, and of our party only one—Lenk—was so fortunate as to reach the desired peak."

Besides the ascents above recorded, several American travelers have published accounts of their trip to the summit.

Mr. Frederick A. Ober in his book, "Travels in Mexico,"* has given a charming account of an ascent made by him "alone with three Indian guides." The date of this ascent he does not state, but from the context one may infer it was in May, 1881. He also quotes an interview with General Grant, in which the latter stated that he had climbed the mountain while stationed at Ameca during the Mexican war. He did so, however, only after a great deal of difficulty.

---

*Page 371.

March 20, 1885, Prof. A. S. Packard, with three guides, ascended the volcano to the crater, and has published a paper giving at some length his observations.* He states that he found the ascent more fatiguing and difficult than that of Pike's Peak or Mount Shasta. Two companions who had undertaken the trip with him were obliged, at the snow line, to return, owing to sickness induced by the altitude.

Of the ascent made by the Expedition of the Academy of Natural Sciences of Philadelphia, April 17, 1889, both Prof. Heilprin† and Prof. Baker‡ have published full accounts. They were accompanied by five guides and carriers and climbed to the Pico Mayor or highest point of the mountain. This point was first attained, as has been stated, by the Glennie brothers.

During the year 1894 the geologists of the Mexican Geological Commission, Messrs. Jose G. Aguilera and Ezequiel Ordoñez, made an extended survey of the mountain from a geological standpoint, and their investigations have given the fullest knowledge yet obtained of its intimate structure. These scientists spent forty-eight hours in the crater, though as they say, *cierto detenimiento*, and ascended the Pico Mayor.

Numbers of tourists have, of course, ascended the mountain who have given no account of their trip, and probably an equal number at least have made the attempt but failed of reaching their goal. I was told while in Ameca that at least thirty or forty every year make the attempt.

It would be interesting to determine whether the greater number of ascents made in recent time as compared with the few of earlier years, indicates that an improvement has taken place in the condition of the race, or whether the failures of early travelers were due largely to imaginary fears. It is probable, however, that the latter is the correct explanation. The following table shows the determinations of the altitude of the mountain which have been made by different observers:

---

*Am. Naturalist, February, 1886.

†Proc. Acad. Nat. Sci. Phila., 1890, p. 255.

‡A Naturalist in Mexico, p. 104.

TABLE OF DETERMINATIONS OF ALTITUDE OF POPOCATEPETL.

	METERS.	FEET.	
Pico Mayor (highest point) W. side of crater.	5,280	17,159	Truqui and Craveri, 1855.
	5,341	17,523	Heilprin, 1890.
	5,391	17,687	Ponce de Leon, Trig. det. 1870.
	5,400	17,713	Humboldt, Trig. det. 1803.
	5,406	17,736	Almazan.
	5,420.4	17,784	Sonntag, 1857.
	5,441	17,851	Birbeck, 1827.
	5,450.9	17,881	Aguilera and Ordoñez, 1894.
	5,450	17,884	Glennie, 1827.
Espinazo del diablo E. side of crater.	5,240.4	17,193	Sonntag.
	5,247	17,215	Dollfus et als., 1865.

My own ascent was made February 18–19, 1896. Having sought in vain in the City of Mexico for a companion, I concluded, like Mr. Ober, to make the attempt "alone with three guides."

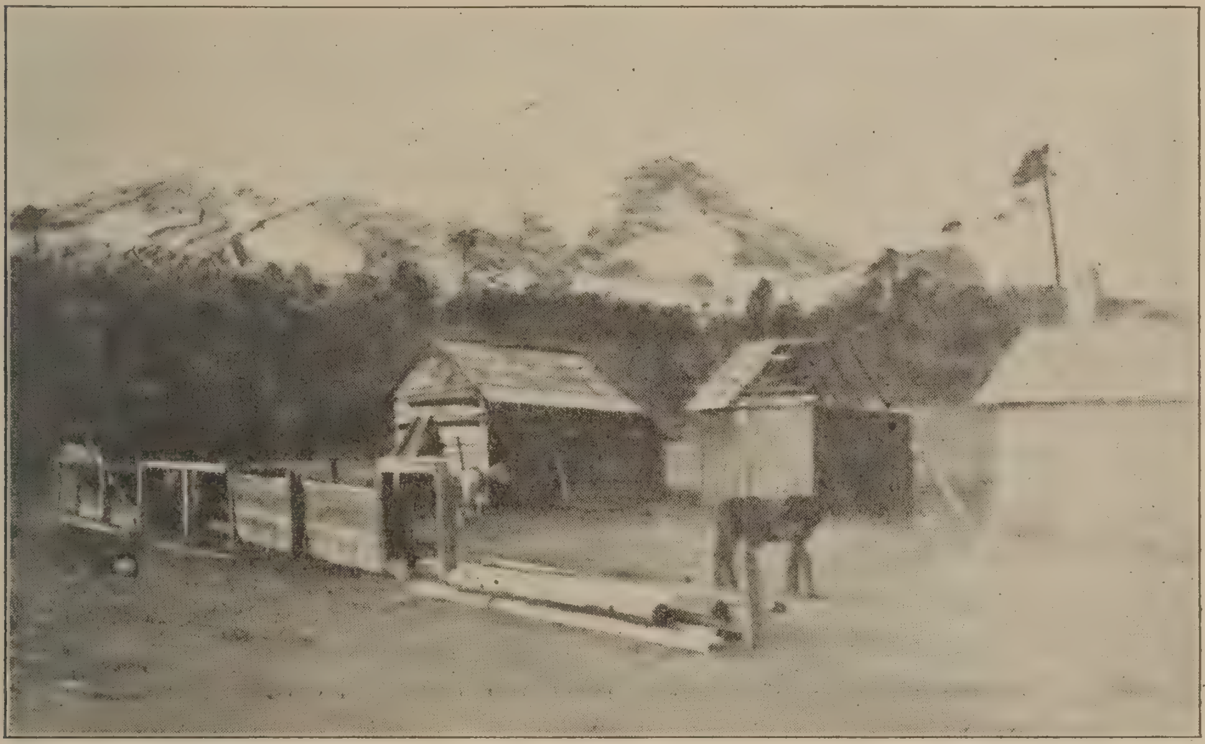
I left the City of Mexico on the 17th, having previously telegraphed Sr. Don Pedro de la Noriega at Ameca to have horses and guides ready for the following day. The morning excursion train on which I had intended to take passage for Ameca was unfortunately, for lack of patronage, not run, so that it was late in the day before I reached the town. This gave me less time than I wished for preparation, but did not cause serious hindrance. After a good night's rest at the hotel, and a delay of several hours caused by the desire of my guides to attend special services at the church, I was ready about 11 A. M. to start. My mount was a small horse which proved tough and serviceable. My guide, Manuel, rode one still smaller, but an animal of wonderful endurance. Upon a pack-mule were placed sacks of barley for the horses, my own provisions and blankets, and the food for the guides—a bundle of *tortillas*. Driving the pack-mule in front of us we started off at a sharp trot under a tropical sun across the plain of Ameca. Behind us came the two Indian guides, on foot, one of whom carried my camera.

For about an hour the road led over the almost level plain of Ameca, amid fields of *maguey* or century plant, and barley and corn. The road was like many of those in Mexico, sunken, being thus with a ditch at each side fenced from the fields. The section of the soil thus afforded showed it to be alluvial with almost no bowlders, the few showing being of the hornblende andesite common about Ameca. Here and there over the plain at intervals a tall dust-spout could be seen to form and whirl its way for some distance ere it was dissipated. I noted similar ones on other plains in Mexico and regarded their frequent formation as due to the "pocket-like" character of the plain, *i. e.*, a more or less circular valley surrounded by high mountain walls.

I have stated that bowlders were comparatively rare, but in the course of a stream crossed about a half hour's ride from the town many of considerable size were seen. There were also some scattered over the plain, but on none of them did I notice marks of glaciation.

Volcanic products can be seen over the portion of the plain about a mile east of Ameca in the form of strata of broken pumice and coarse ashes. These can be followed for some distance up the mountain.

After a ride of about an hour the foothills, low and rounded and made up of alluvial soil with gravel and bowlders, were reached. Most of the hills were cultivated. These hills, according to Packard, have every appearance of being moraines, but as I have previously stated, they appeared to me to be rather of lacustrine origin. The artificial hill of Tetepetongo, previously mentioned, lies at the right of the road among them, rising out of a cornfield. The flora over these hills was far more brilliant than on the plain, probably on account of the greater supply of moisture. Stately yellow-flowered shrubs of the order of Compositæ, a red labiate flower and blue columbines were the most numerous among the flowering plants. Passing these we advanced into dense woods made up of firs and cedars, through which the trail wound now to the right and now to the left, but always upward. From favorable points on the trail could be gained charming views of the plain continually left farther below and exposing ever a greater expanse to the eye. Inspiration was lent by the thought that the scene was but little changed from that which greeted the eyes of Cortes and his band as they pushed on over the same trail from the side of Puebla nearly four hundred years before. At intervals the trail skirted the brink of a deep barranca or ravine, that of Zumpango, which was formed by a mountain stream. The rock cut through by the stream appeared to be a basalt, but I did not approach near enough to procure any specimens. It is described by Felix and Lenk as differing from the prevailing andesite of the mountain in possessing a relatively large content of olivine. The amount of water in this and other streams crossed was naturally small, as it was the dry season and the only source of supply was the melting snow of the cone. After about two hours' ride through woods such as I have described, we came out upon a series of well-marked plateaus which extended nearly to the cone itself. The temperature was here considerably colder than on the plain, and the general aspect was quite that of a New England pasture land in May. Long stretches of dry grass were dotted here and there with stunted pines, in the branches of which robins and blue birds chirped and twittered. Another stretch of pine woods was then encountered in a region deeply intersected with ravines. The trees here were of considerable size and thickly distributed. To the left of the trail rose the rugged peak of Cerro Tlamacas, belonging to the ridge which extends northeast from Pico del Fraile. This ridge seems to have had an independent origin from the main cone, as is indicated both by its topography and the character of its rock masses. Its rocks are a vitreous andesite and trachytes, none of which contain augite.* Areas of sand thrown out at some time from the volcano were common hereabouts, as were also tumuli of pumice, the latter a light, felt-like scoria containing tabular crystals of feldspar and augite disseminated through its mass.



Copyright by Schlattman Brothers.

FIG. 1. THE RANCH OF TLAMACAS.

About 5 P. M. we arrived at the Ranch of Tlamacas. This is simply a collection of rude shanties used for housing the men who mine sulphur in the crater and for carrying on the refining of sulphur. The sulphur is at present mined for only about two months of the year, June and July. These months are chosen because at this sea-

---

*Aguilera and Ordoñez, *op. cit.* p. 47.

son the quantity of snow on the cone is sufficient to allow of making a smooth trough on which the sulphur can be slid from the crater to the ranch. All of the sulphur which has gathered in the crater during the year, so far as it is accessible, is taken out at this time. The sulphur is refined simply by heating in large earthen retorts. From these it passes over into other earthen jars and condenses. The process is crude and simple, but the product obtained is quite pure and free from the sand and other impurities which were intermingled with it in the original deposit.

The following table shows altitudes in this region as they have been determined by different observers:

ALTITUDES OF POINTS NEAR THE RANCH OF TLAMACAS.

	METERS.	FEET.	
Ranch of Tlamacas	3,897	12,786	Dollfus, 1865.
	3,899.4	12,794	Sonntag, 1857.
	3,931	12,897	Aguilera and Ordoñez, 1894.
Cerro Tlamacas	4,072	13,359	Sonntag.
La Cruz	4,300	14,108	Felix and Lenk, 1887.

On dismounting from my horse at the ranch I noticed for the first time symptoms of mountain sickness due to the altitude. I found myself exceedingly dizzy, my heart beat violently and I was obliged to pant in order to supply my system with sufficient air. I had also considerable nausea, throbbing of the temples, and other indications that my system revolted at being raised to so great an altitude. The acuteness of the symptoms wore off in an hour or two, but the excess of blood at my head continued in sufficient force to prevent much sleep that night, and the nausea persisted with greater or less severity throughout the following day. Not all travelers experience these symptoms to the same degree, but the strain on the heart and lungs especially is so severe that no one not possessed of sound organs should essay the height.

After a cold and sleepless night at the ranch we mounted our horses about 6 A. M. for the ascent of the cone. The first part of the way lay through a growth of pines which gradually became more stunted and scraggly till they disappeared entirely at an altitude determined by Aguilera and Ordoñez as 13,222 feet.

The Barranca of Tlamacas was then crossed, giving an opportunity to see a section of some of the overlying strata. The barranca is produced by the downflow of the waters gathered in the semi-circular depression between the Pico del Fraile and the eastern slope of the cone. As is indicated on the map (Pl. XVIII) the stream has a course nearly north for some distance, then turns to the northeast and east, and empties its waters into the valley of Puebla. The barranca has a depth, where the trail crosses it, of about 60 feet. The strata exposed in section here have been fully described by Aguilera and Ordoñez* as follows: Below the black sand, which covers everything in this region, appears, first, a red breccia, made up of fragments of andesite joined together by an argillaceous cement; second, a grayish breccia of pumiceous fragments less coherent; third, one of coarse fragments of andesite, and fourth, one of fine, pumiceous materials. These breccias show consolidation by percolating waters, but no sorting of materials or stratification such as would indicate deposition by water. They probably, therefore, lie very much in the order in which they were thrown out by the volcano.

Crossing the barranca of Tlamacas the trail passed on in a general southeast direction over the layers of black sand or cinders which everywhere cover the cone. These cinders are simply comminuted fragments of the glassy, hypersthene andesite which makes up the mass of the cone. The particles are somewhat rounded by attrition, but show many edges so sharp that one must conclude that the sand is either of recent formation or else has not been much shifted by the winds. The degree of division varies considerably from that of the finest ashes to fragments as large as one's fist. Some trials which I made indicate that the average coarseness of the sand is such that the largest portion will pass between a 35-mesh and 30-mesh sieve. There are areas where a much greater degree of coarseness prevails, and many bowlders scattered about are a cubic foot or more in dimension. The rough, angular surfaces and scattered situation of these larger masses indicated that they were thrown out with the sand during explosive eruptions. Beyond the limit of trees, vegetation continues over the slopes as a long, wiry grass to a point about 500 feet higher, although the sands blown about by the winds frequently cover the grass and choke it out. The determinations of the altitude of the limit of vegetation and snow line for the different portions of the mountain may be found in the following table:

---

*Op, cit. pp. 12 and 37.

ALTITUDES OF SNOW LINE AND LIMIT OF VEGETATION ON POPOCATEPETL.

	METERS.	FEET.	
Height of snow line on the West side, January	3,700–3,800	12,139 12,464	Humboldt, 1803.
Height of snow line on the West side, September	4,500	14,764	Humboldt.
Height of snow line on the North side, December	4,400	14,436	Felix and Lenk, 1887.
Height of snow line on the North side	4,350	14,272	Aguilera and Ordoñez, 1894.
Height of snow line on the South-east side, April	4,300	14,105	Dollfus, 1865.
Limit of vegetation, East side	4,180	13,714	Dollfus.
“ “ “ North side	4,023	13,200	Sonntag, 1857.
“ “ “ West side	3,845	12,615	Gerolt, 1834.
“ “ “ “ “	3,869	12,694	Glennie, 1827.
Limit of trees, North side	4,030	13,222	Aguilera and Ordoñez.
“ “ “ Northwest side	3,639	11,939	Sonneschmidt, 1770.
“ “ “ South-southwest side	3,823	12,543	Glennie.
“ “ “ East side	3,980	13,048	Dollfus.

The advance over this part of the trail was very painful for the animals on which we were mounted, owing to the loose footing and rarefied air, and they could take but a few steps before they were obliged to stop and rest. After a ride of somewhat more than an hour, the point called La Cruz was reached, and from here the ascent of more than three thousand feet, had to be made on foot. A rough, wooden cross erected at this point gives to the place its name of La Cruz. This cross is said by some to have been erected, in accordance with the Mexican custom, in memory of a man who died in the crater, while by others it is said to have been used as a shrine before which the sulphur miners in earlier times knelt to give thanks, after a safe return from their perilous journey to the crater.* The rough bosses of the lava stream project in this region above the smooth slope of sand with which most of the cone is covered, and give a wild and desolate aspect to the scene. The rocks are chiefly the red, slaggy breccias and grayish-black, compact andesites seen later at the northeastern edge of the crater. The close similarity observable in the rocks of these two regions is regarded by Aguilera and Ordoñez† as sufficient proof that they belong to one and the same lava flow, the connecting area being supposed to have been lost through erosion or to be hid by the covering of snow and sand. Other observers, however, look upon the prominence of the lavas at this point, as well as the fact that a broadening of the stream is visible as it descends the slope, as indicating that a lateral outburst

---

*Felix and Lenk, *op. cit.* p. 24.

†*Op. cit.* p. 32.

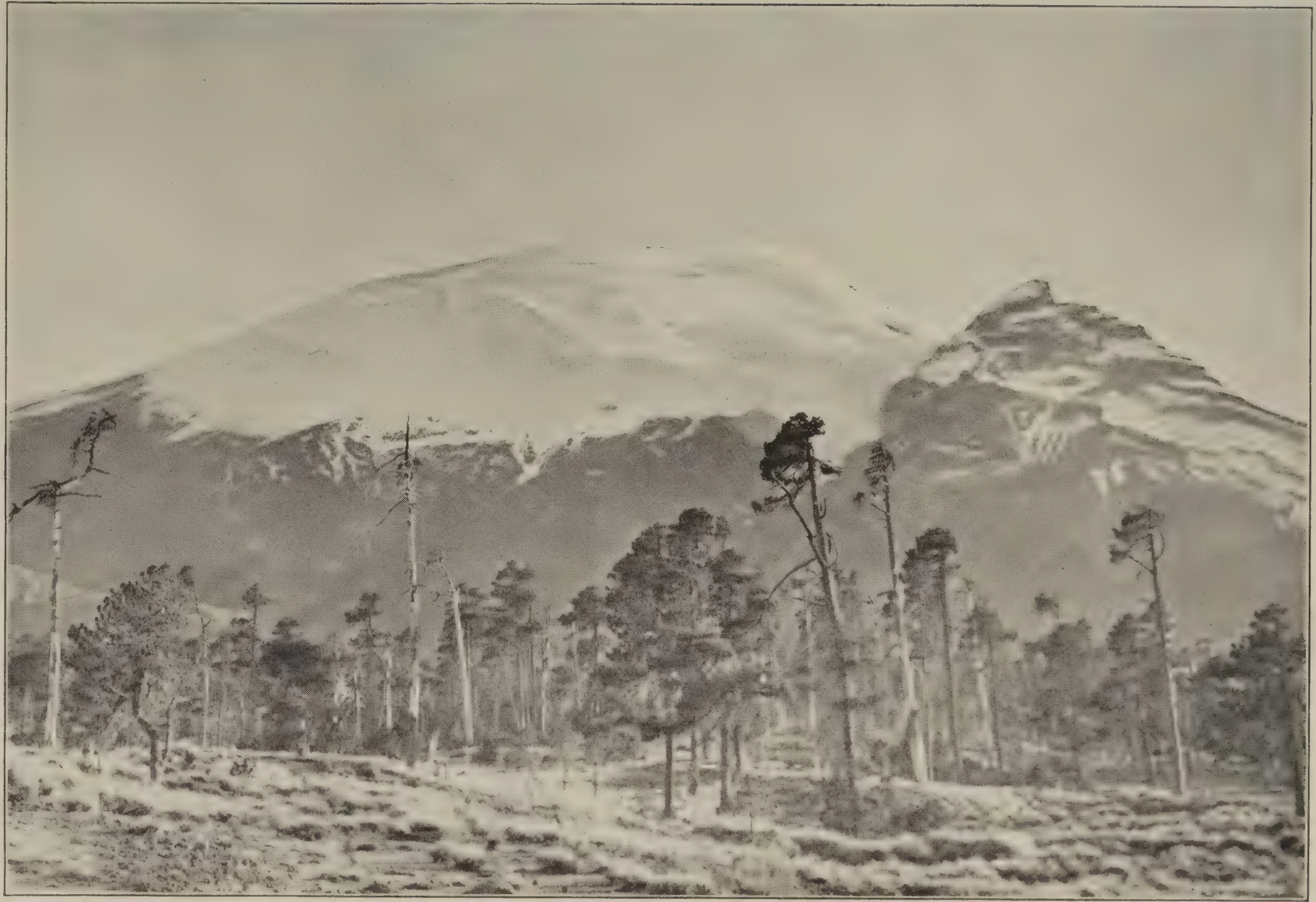


Photo. by the Author.

(Pico del Fraile.)

Upper Cone of Popocatepetl as seen from the Ranch of Tlamacas.

through the side of the cone took place here. The topography of the surface is certainly such as to favor this latter view, and as will be noted later, considerable difference can be seen microscopically, between the rocks of the two regions.

Another peculiarity of the rocks of the region has given rise to differences of opinion as to its origin. This is the flat, polished surfaces to be observed truncating the solid angles of projecting masses of the lava. According to Felix and Lenk,* since these surfaces display no scratching or grooving, and appear on all sides of the rock masses, they can not be due to the action of snow or ice, but are the result of Æolian action, i.e., the movement of the sand-bearing winds. Aguilera and Ordoñez,† however, finding no relation between the direction of the prevailing winds and the position of the polished surfaces, and noting that the polishing is as complete in places sheltered from the winds as in those exposed to them, regard the smoothing as brought about by the action of ice and descending waters. My own opportunity for observing these surfaces was not sufficient to enable me to form an opinion as to their probable origin.

Arriving at La Cruz, the horses and mounted guide were sent back to the ranch and arrangements were made to continue the ascent on foot. This required fitting the feet with *guarachos* or thick, broad sandals of heavy leather, around which several layers of burlap were wrapped. These insured warmth, but were worn primarily for protection to the shoe soles. So destructive are the ice and ashes to ordinary leather that a pair even of the *guarachos* is worn out in a single ascent. As this was the dry season the snow line was not encountered till we were several hundred feet above La Cruz. During the wet season, however, the snow and ice descend nearly to the Ranch of Tlamacas. Though the surface of the cone above the snow line is in general snow-covered, there are many long tongues of sand exposed on the lower parts of the slope. Upon these, so far as possible, we made our ascent, for, made firm by the freezing of the water with which they are saturated, the sand slopes afford a better foothold than the rough snow and ice. Over this surface we toiled until only a white field of snow separated us from the summit. To advance over this, every step had to be cut in advance by the guide. The vertical rays of the tropical sun cause the melting of the snow to take place in a direction parallel to the rays, but at an acute angle with the slopes. Then while the sun's rays cut the snow surface vertically, the rills formed from the melting snow waters cut it laterally. The

---

**Op. cit.* p. 24.

†*Op. cit.* p. 33.

result is that the surface of the snow field is cut into numberless, rough, wedge-shaped teeth. Over these, progress is very slow and difficult. The snow is rarely more than a few feet in depth, a fact to be accounted for by the regular slope of the cone and the permeability and dark color of the ash bed on which the snow lies. The ashes, retaining heat, melt the snow and drain away the water constantly from the under surface of the snow field. In depressions, the snow accumulates to a greater depth, but never to an amount that would make the formation of a glacier possible. The nearest approach to this is found at the foot of the Pico del Fraile, where the snow presents something of the character of a glacier.* Nothing like crevasses occur in the snow, and the yawning chasms reported by travelers, or would-be travelers, can be set down as purely imaginary. Besides the difficulty of ascending over so rough and steep a surface, other difficulties of the ascent are the cold, which is, of course, of varying degree, but has been sufficient to freeze the feet of tourists; the fierce wind produced by the descent of the air which has been chilled by the cold slopes of the mountain, and the excessive fatigue caused by the fact that the heart and lungs are compelled to work at about twice their normal speed in order to gain from the rarefied air sufficient oxygen for the system. These difficulties may well be considered before an attempt to ascend is made, but if the system is sufficiently strong to endure these hardships no other danger need be feared.

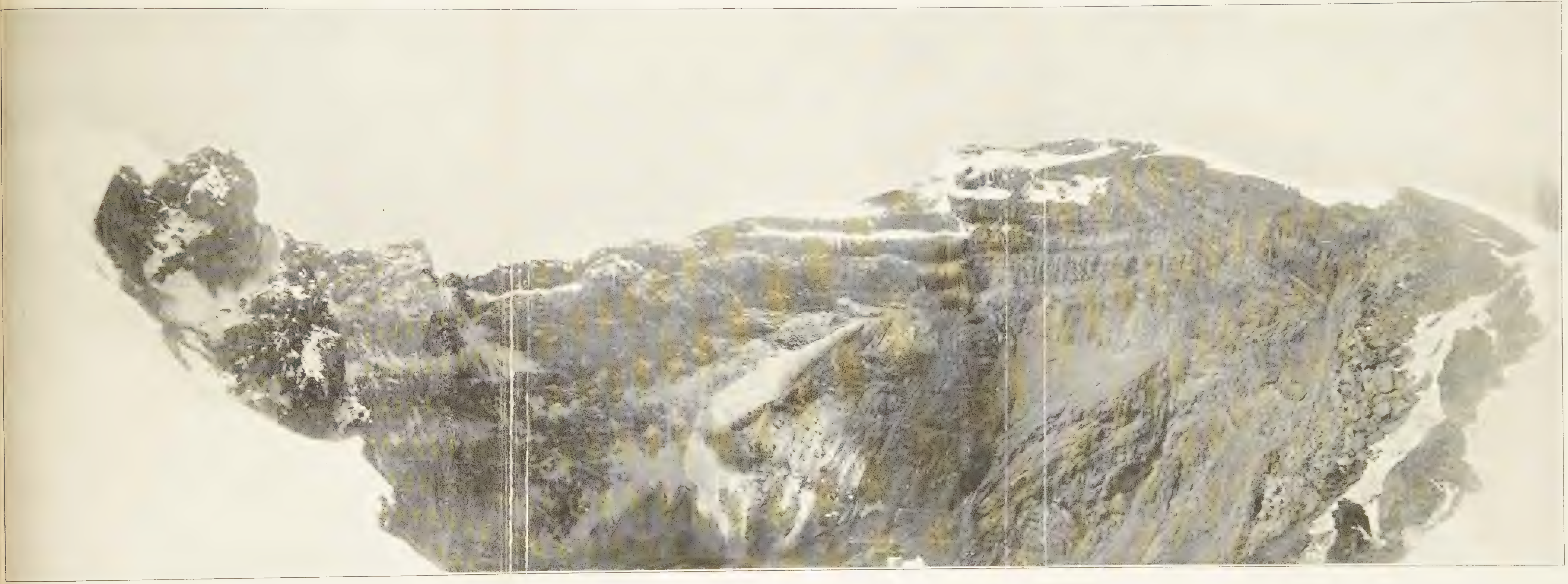
It was about 11 A. M., after four hours of toilsome climbing on foot, that the first suggestion of the proximity of the crater came in the form of a strong odor of hydrogen-sulphide which filled the air. A little later the guide in front shouted: "*Llegamos!*" (We are there), and we came out upon a ridge of ashes whence we could look into the yawning depths of the crater below.

Let one imagine a pit about 2,000 feet in its greater diameter, 1,300 in its lesser, and from 800 to 1,500 feet in depth, let down into the summit of the mountain, from different points in the nearly perpendicular walls of which jets of steam come hissing and sizzling, and rocks of varying size continually fall from the walls of the crater and plunge with a roar to the bottom; imagine that the bottom is heaped unevenly with debris of various sorts and colors, and that all this must be observed in a wind so fierce that it causes the very walls of the crater to tremble, and one gets a good idea of the first impression made upon the observer by the crater.

There is nothing of the heat and movement which might be expected from being at the point of issue of the volcanic forces, for,

---

*Aguilera and Ordoñez, *op. cit.* p. 18.



(El Espinazo del Diablo.)

(El Portezuelo.)

(Pico Mayor.)

CRATER OF POPOCATEPETL AS SEEN FROM THE NORTHEAST.

Copyright by Schlattman Bros.

as has been said, only a stage of solfatara activity exists. The steam jets afford cold comfort, and nothing tempers the severity of the wind. A temperature of −11.8 C. (+11° F.) was observed here by Sonntag* at one time.

We descended on the northeast side of the crater, nearly to the windlass which has been erected for the purpose of lowering the sulphur miners. It was only then that my guides told me that two more men would be necessary to work the windlass so as to permit my descent. I was much disappointed in this, for I had hoped to reach the floor of the crater and to explore it with some care. Under the circumstances, however, I was obliged to be content with studying it from above.

The crater is situated eccentrically as regards the main axis of the mountain, the latter having a northwest-southeast direction, while the major axis of the crater is directed northeast-southwest, or nearly at right angles to this. This would indicate a shifting of the eruptive point. The rim of the crater is of variable height, the lowest point being at the northeast, the highest at the northwest. The greater elevation of the western wall, as compared with the eastern, Sonntag calls attention to† as being a common feature of nearly all the recent craters. He mentions Orizaba, Colima, Toluca and San Isidro as illustrating this. He suggests that the trade winds, which in this region blow from east-northeast, may perhaps furnish an explanation of this peculiar elevation of the western above the eastern rims.

Various parts of the crater rim have received names by which they are usually designated. Thus, the peak at the northwest is called "Pico Mayor" (the highest point); the depression at the south end "El Portezuelo" (the little door); the ridge at the east, "El Espinazo del Diablo" (the devil's backbone); the lowest portion at the north and northeast, "El Labio Inferior" (the lower lip), and the point at which the windlass is erected, "El Malacate" (the windlass), or Brecha Siliceo. The depth of the crater, from the irregular heaping of tumuli on its floor, naturally varies greatly. As noted in the table, Aguilera and Ordoñez determined the greatest depth from the surface of the little lake in the crater to the highest point of the Pico Mayor to be 1,657 feet, while from the Malacate it was only 673 feet. They thus found a difference of nearly 1,000 feet in the depth of the crater, as determined from the different points. Other determinations and dimensions are given in the following table:

Op. cit. p. 57.

†*Op. cit.* p. 53.

TABLE OF DETERMINATIONS OF DIMENSIONS OF CRATER.

	METERS.	FEET.	
Greater Diameter of Crater.	400	1,312	Topf, 1886.
	600	1,968	Felix and Lenk, 1887.
	612	2,008	Aguilera & Ordoñez, 1894.
	800	2,624	Dollfus et als., 1865.
	825	2,668	Sonntag, 1857.
	1,524	5,000	Gerolt and Gros, 1834.
	1,600	5,248	Glennie, 1827.
Lesser diameter of Crater.	200	656	Topf.
	400	1,312	Felix and Lenk.
	400	1,312	Aguilera and Ordoñez.
	740	2,373	Dollfus et als.
	1,219	3,999	Gerolt and Gros.
Depth of Crater...........	150-180	492-591	Pieschel, 1853.
	About 250	820	Dollfus et als.
Depth from the Malacate (Windlass)...............	205	673	Aguilera and Ordoñez.
Depth from the Brecha Siliceo.....................	50	164	Topf.
	150	492	Felix and Lenk.
	164	527	Sonntag.
	244	800	Gerolt and Gros.
Depth from the Pico Mayor	60	197	Topf.
	305	1,001	Gerolt and Gros.
	311	1,020	Sonntag.
	505	1,657	Aguilera and Ordoñez.

In the walls of the crater the layers of lava of which it is made up are plainly visible, being seen best on the western side. These layers do not lie horizontally, but dip at various angles. No layer can be traced entirely around the crater by the eye, though obviously each flow was likely to have found exit at various points along the rim. The layers are separated by strata of volcanic sand, scoria, etc., which being more easily eroded than the solid lava, leave the latter projecting from the walls. The interspersion of the loose volcanic products indicates that after each lava flow coarse blocks and showers of sand were ejected, to be more or less consolidated and cemented before the next flow. These loose products have frequently, moreover, been further cemented by the lava of the succeeding flow into a firm breccia, which forms in some portions of the crater the only layer intervening between the more compact lavas. As previously noted, such breccias also occur about the region of La Cruz. The lavas about the crater vary in color from red to black, according, apparently, to the degree of oxidation of the iron.

The present activity of the crater is limited to the exhalation of steam from various points in the crater walls and the floor of the crater. Other gases accompany the steam, especially hydrogen-sulphide and sulphurous acid, and combining, form sulphuric acid

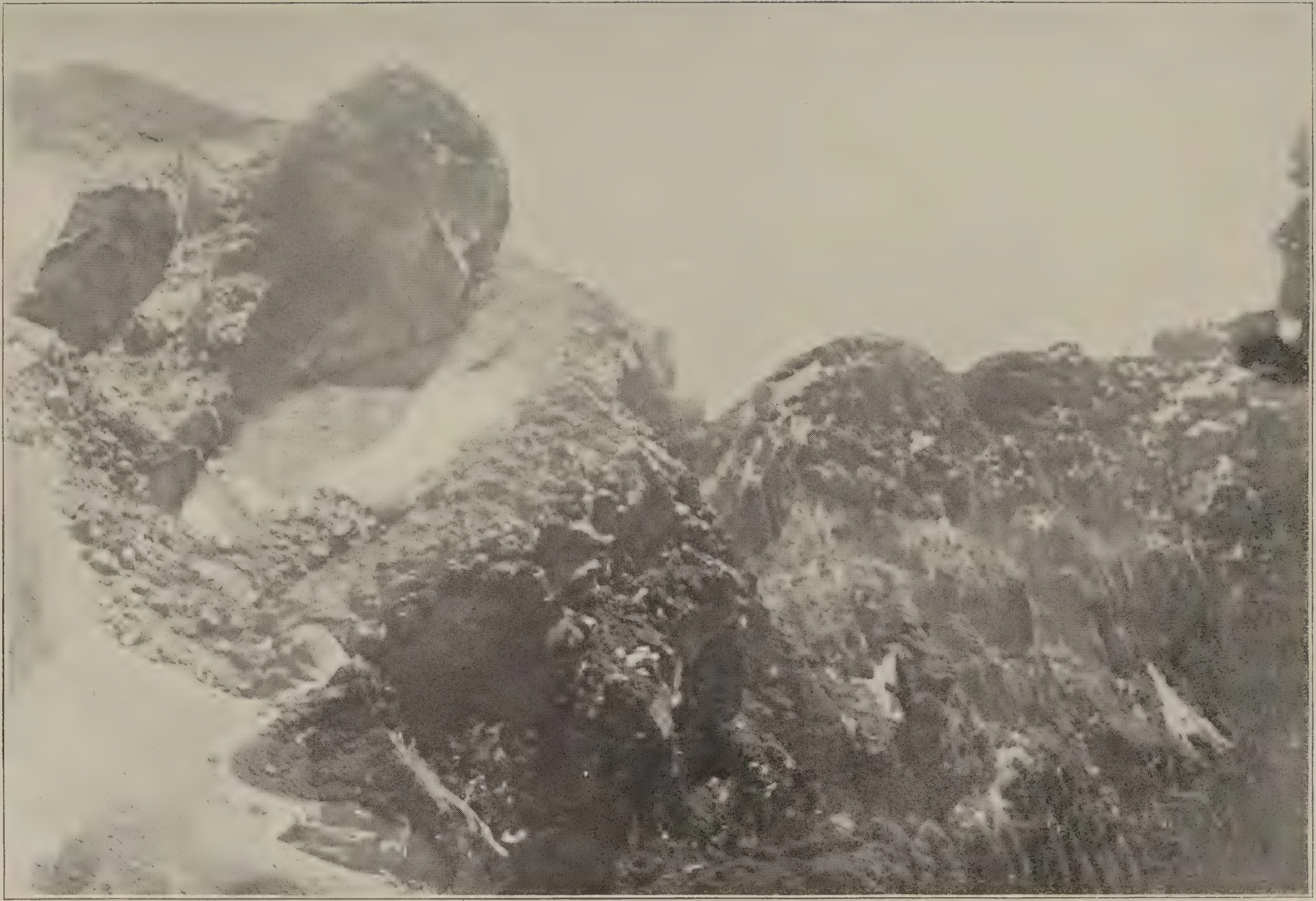


Photo. by the Author.

EASTERN WALL OF CRATER.
(El Espinazo del Diablo.)

The cliff at the left shows variations in the texture of the lava. Strata of compact texture alternate with porous and brecciated layers.

and sulphur. The latter is deposited about the vents. This sulphur, where accessible, furnishes the source of supply to the miners. The escaping fumes cause considerable alteration of the surface of the lava walls and give them, especially on the southern side, a peculiar yellow color. The number and position of these vents seems to be variable. Packard quotes General Ochoa as stating that there are more than sixty. Felix and Lenk* state that Topf noted four in June, 1886, while at the time of Dr. Lenk's visit, December, 1887, there were seven. At the time of my visit there were six. Two of these, on the east and west crater walls, seem to have a pretty constant location, as do also two on the floor of the crater near the south wall. The floor of the crater is not level, but is heaped up with tumuli of various sizes from accumulations of material fallen from the crater walls. In the southeast portion is a little lake which varies in size at different seasons. Its supply comes from falling snow, which is nearly all melted by the warmth of the crater. The condensation of the warm, moist air rising from the crater, upon meeting the cold of the summit, causes clouds, which may have been mistaken by observers at a distance for smoke. The debris on the floor of the crater is constantly being augmented in quantity by rocks which fall from the crater walls. These are detached chiefly by the frost, which is continually at work. Sonntag† estimates the rise in the floor of the crater to be 0.65 of a foot a year from this cause, but calls attention to the obvious fact that the rise will be less every year, as the upper part of the crater expands. According to Aguilera and Ordoñez, the walls of the crater are growing constantly more nearly vertical, but this view has previously been criticised by the writer.‡

The view of distant places from the mountain was hindered by a sea of fleecy clouds which covered all below except only the peaks of Ixtaccihuatl to the north and Orizaba to the east. After about an hour spent upon the summit, descent to the ranch was made in less than one-fourth of the time required for ascent. The descent was attended with little difficulty, none of the hardships of the ascent being encountered. When there is sufficient snow on the slopes the Indian miners slide down on mats the entire distance, but this can be done only during the wet season. When part way down we passed through the clouds which enveloped the mountain. These appeared like a cold, drifting fog about a thousand feet in thickness. They were cumulus clouds, formed undoubtedly by the cooling of the moisture of the air by the snow-covered

---

**Op. cit.* p. 25.

†*Op. cit.* p. 58.

‡Jour. Geol., Vol. IV, No. 4, p. 516.

summit. The clouds usually envelop the mountain during the latter part of the day.

Reaching the ranch about 4 p. m. another night was spent there, and before noon of the following day we had arrived again at the hotel in Ameca.

EL PICO DEL FRAILE.

(THE FRIAR'S PEAK.)

The position and general character of this peak have already been referred to (p. 81). See also Pl. X.

It rises on the northwest side of the principal cone to a height only about 1,000 feet less than that of the cone itself. On the side away from the cone it displays a marked amphitheater-like structure. It is principally of interest as being a point usually gained in earlier times by explorers who attempted an ascent of the mountain, and also as having provoked much discussion as to its origin. Its general appearance makes it at first sight seem to be the remains of an earlier crater of which less than a fourth is now left. Its projecting peak, its semi-circular shape and its constitution of distinct layers of lava between which strata of loose volcanic products intervene, all point to the correctness of this supposition. If it be an older crater a shifting of the eruptive center has evidently taken place to the southeast, for this is the direction in which the present cone lies. But this view of the origin of the peak, though it has been usually held hitherto, is now strongly opposed by the Mexican geologists, Aguilera and Ordoñez.* In their opinion the Pico del Fraile is but a portion of the principal cone which has been isolated by erosion. They base their opinion, first, on the fact that the layers of lava and breccias which in varying order compose the peak, are of so loose structure as to expose it strongly to disintegration, and secondly, on the fact that the slope of the layers which form the peak is exactly that of the strata of the principal cone. Had a crater been located here, they argue, the layers should slope outward from the crater and at right angles to their present dip. While it would be no unusual occurence to find strata sloping inward in a crater, it hardly seems likely that these would follow so closely the inclination of the principal slope were they not identical in origin with the latter. The separation of the peak the authors account for as having taken place through transverse crevices which were entered by waters; surrounding areas were removed, thus leaving the peak standing in relief. Should any origin prior to that of the principal cone be assigned

---

**Op. cit.* p. 28.

to the peak, they would prefer to connect it with a somewhat similar elevation on the southeast and regard the two as the remains of an earlier crater corresponding to the Monte Somma of modern Vesuvius. Not having been able to visit the Pico del Fraile myself I am unable to give any opinion on the question at issue, but the problem is an interesting one for further study.

DETERMINATIONS OF THE ALTITUDE OF EL PICO DEL FRAILE.

METERS.	FEET.	
5,004	16,418	Sonneschmidt, 1770.
5,050.1	16,570	Sonntag, 1857.
5,142	16,870	Gerolt, 1834.

PETROGRAPHY.

The lava outcropping at La Cruz and seen in scattered fragments about this portion of the mountain is a compact hypersthene-andesite of grayish-black color. Owing to the glassy nature of the feldspars, the general lack of conspicuity of the phenocrysts and the conchoidal fracture of the rock, it has a strong resemblance to obsidian. No true obsidian is, however, known in the region. Upon weathering, certain areas take on a reddish tone.

Megascopic examination shows the rock to possess a porphyritic structure; the white or light-colored phenocrysts are feldspar, the dark-green grains, pyroxene. The feldspar phenocrysts are small compared with those of the andesite of Ixtaccihuatl; they rarely exceed 2 mm. in length. They do not have well formed crystal outlines, but so far as these appear they show the habit of the feldspars to be tabular. Distinct crystal outlines can rarely be determined for the pyroxene, the mineral occurring as coarse grains or lining druses.

Under the microscope the ground mass is seen to have the typical hyalopilitic or felt-like structure. It is made up chiefly of minute microlites averaging .02 mm. in length, and trichites with some margarites. The microlites are probably feldspar laths but their extremely small size prevents accurate determination. Quite a large proportion of the base is isotropic or glassy. There are indications of a gathering of the microlites into bundles to give a variolitic or subspherulitic structure. Opaque grains numerous in the ground mass are presumably iron oxide.

The feldspar phenocrysts are idiomorphic and many display beautiful zonal structure. Many of them contain magmatic and gas inclusions which are arranged in zones. The species of feldspar indicated by observation of the angle of extinction on the albite lamellæ is labradorite, the highest angle of extinction observed being 28°.

The hypersthene phenocrysts are quite as numerous as those of feldspar, but of smaller size. The crystals are of prismatic habit with *a* (100), *b* (010), predominant, and *m* (110), subordinate. Sections across the prisms show rectangles with truncated corners in which the prismatic and pinacoidal cleavages || to *b* (010) are well marked. The color is green to brownish according as the section is parallel with the prism or at right angles to it. The pleochroism is, 𝔞, reddish brown; 𝔟, reddish yellow; 𝔠, light green.

Beside the individual phenocrysts there are numerous aggregates without apparent twinning plane, as well as intergrowths of hypersthene and feldspar. Magnetite is common in grains though not abundant.

The rock at the edge of the crater is, as might be expected, more porous and slaggy than that at La Cruz. Being more subject to weathering processes it is largely reddish or chocolate-brown in color. It breaks with a coarse-granular rather than a conchoidal fracture. The phenocrysts are neither as numerous nor as large as those of the rock of La Cruz. This is accounted for, as already mentioned, by the fact that this lava was farther from the source of heat and had less time for cooling. As in the rock of La Cruz, the phenocrysts are lath-shaped feldspars and grains and druses of pyroxene. There are numerous grains of pyrite noticeable as well. It is probably of secondary origin. The ground mass as a rule is light-brown in color and made up of microlites of feldspar and augite not over .02 mm. in length. In portions of the section the ground mass becomes completely isotropic and has a marked fluidal arrangement about the phenocrysts. The phenocrysts are smaller and less numerous than in the lavas of La Cruz, but in other respects do not differ.

A monoclinic pyroxene, probably augite, is present in large phenocrysts. It can be distinguished from the hypersthene by its inclined extinction. Twins are occasionally to be seen, the twinning plane being the common plane, *a* (100).

The microscopic structure of the rock marks it as quite distinct from that of La Cruz. There is therefore reason to doubt the view of Aguilera and Ordoñez that the rocks belong to the same lava flow.

The following analysis (I.) of the typical hypersthene-andesite of the region, and for comparison an analysis (II.) of the hypersthene-andesite of Mount Shasta, California, is given by Felix and Lenk.*

	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	CaO	MgO	K_2O	Na_2O	P_2O_5	H_2O	Sp. Gr.
I.	61.06	trace	15.42	8.01	not det.	....	7.11	3.55	1.40	2.66	trace	0.68	2.658
II.	62.00	0.17	17.84	....	4.40	trace	5.37	2.64	1.47	4.29	0.29	1.66	.....

---

*Op. cit. p. 100.

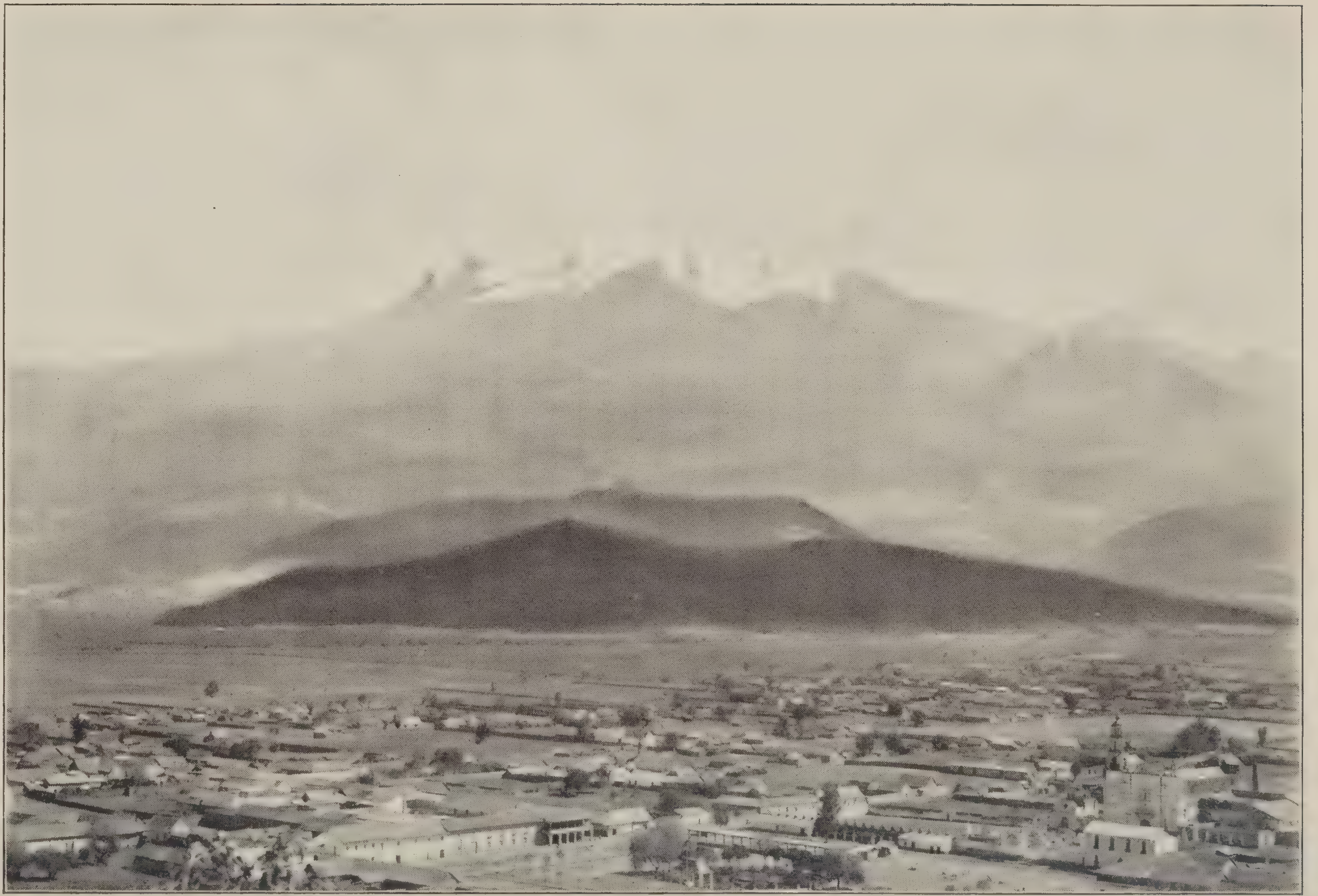


Photo. by the Author.

IXTACCIHUATL FROM AMECA.

IXTACCIHUATL.

Ixtaccihuatl (pronounced Is-tak-*see*-watl) lies almost due north from Popocatepetl, its distance from the principal peak of the former mountain being about ten miles. In shape and outline it differs strikingly from Popocatepetl, since instead of having the rounded, conical form of the latter, it consists of a long, narrow ridge cut into three well-defined peaks. These peaks are about equidistant from one another, and the central is the highest. The length of the ridge from the northern to the southern peak is little less than two miles.

The snow-covered portion of the mountain has quite a striking resemblance to the figure of a woman lying on her back. Hence the name Ixtaccihuatl, meaning the White Woman (*ixtac*, white, and *cihuatl*, woman), given to it by the Aztecs. Of this figure the northern, central and southern peaks represent the head, breast and feet respectively. According to the tradition of the Aztecs* the woman was a goddess, who for some crime had been struck dead, and forever after was doomed to lie rooted to the spot. Popocatepetl was her lover, who, being unwilling to desert his spouse, remained by her side, and gave vent to his sorrow by great heavings and groanings of his breast, and floods of lava tears.

Whatever may have been their views regarding the origin of Ixtaccihuatl, neither the Aztecs nor their successors seem to have made any extensive exploration of it. Both popular and scientific attention has been so largely turned to its higher neighbor, that Ixtaccihuatl has received comparatively little notice.

From a scenic point of view, however, Ixtaccihuatl far surpasses its better known companion. Its sharp, rugged outlines, aiguille-like summits and comb-like ridges, its precipitous escarpments, and deep, narrow valleys, give it a wild and imposing aspect, which is everywhere softened to the pleasing and picturesque by dashing mountain streams, charming glens, and a rich and varied flora. The scenery, indeed, is said strikingly to resemble that of the Alps both in grandeur and variety.

I am aware that I do not express the opinion of all writers in thus giving the palm of beauty to Ixtaccihuatl, for Packard† at least,

---

*Ober, *op. cit.* p. 374.

†*Op. cit.* p. 109.

says that Popocatepetl is the grandest mountain summit of the valley of Anahuac. To my own mind, however, Ixtaccihuatl presents by far the most striking scenery.

Turning to a history of the various attempts made from time to time to ascend this mountain, we may find them briefly summarized in the work of Felix and Lenk.*

"The cool assertion of Father Sahagun of the 16th century," say these authors, "that 'he had been to the top' is as little to be believed as is his statement that in the case of Popocatepetl he had reached the highest point, and won the honor of the first ascent.

"The honor of having made the first attempt at ascent belongs to Frederick Sonneschmidt, the traveler who about the end of the 18th century undertook the first barometric measurements of Popocatepetl, and gained at least the height of the Pico del Fraile. From Sonneschmidt's description it seems quite certain that he did not ascend the highest or middle peak of Ixtaccihuatl, but only the lowest or southern, a conclusion which is corroborated by his barometer measurement of 4,516m.

"When in 1803 Humboldt carried on his trigonometric measurement of Popocatepetl in the Llano de Tetimba, he determined at the same time the height of Ixtaccihuatl and found it by calculation to be 4,786m.

"A long time passed after this before another traveler attempted to ascend the mountain.

"On the 15th of April, 1853, however, the French engineer and geologist, Virlet d'Aoust, again made the attempt to ascend the highest peak. In this he was not successful, but he reached one of the two ridges which separate the three peaks of Ixtaccihuatl from one another. Unfortunately, except for a determination from the boiling point of water at the Rancho de la Sienega (above Tlalmanalco on the west side), which gave about 3,168.5m., no measurements of heights were undertaken by Virlet d'Aoust.

"A. Sonntag, a member of the scientific commission which was sent to make geodetic measurements of Popocatepetl, unacquainted, as it seems, with Virlet d'Aoust's undertaking, spent some days in February, 1857, on the slope of Ixtaccihuatl, and on the 5th of February ascended actually to the snow line.† His was the last

---

Op. cit. p. 51.

†Felix and Lenk here state that Sonntag did not aim to reach the highest peak, but only to search for traces of a certain Dr. Cramfort, who, after an attempt at ascent concerning which nothing further is known, disappeared. In his published observations (Smithsonian Contributions to Knowledge, Vol. XI, p. 60), however, Sonntag makes no mention of such a search, only stating that he reached without much difficulty a point which he considered to be about 600 feet vertically below the highest peak.

expedition to the mountain, till Dr. Hugo Topf, of Puebla, improved an opportunity gained on his return from an ascent of Popocatepetl to reconnoiter the other mountain. On its south side, in so doing, he reached a height of about 4,000m." The result of this reconnoiter was an attempted ascent which Lenk made in April, 1888, in company with Topf, the survey by the latter having shown that the best route was that from the southwest. The gentlemen reached the glacier on the morning of April 12, and with two guides gained about 1 P. M. a point which was estimated to be about 150m. below the highest peak. The height of this point they determined to be 4,666m. Here they were driven back by a violent storm of snow, and no further opportunity of ascent was afforded.

November 9, 1889, according to a reference made in the Geographical Journal,* Mr. H. Remise Whitehouse made an ascent of the mountain and found upon the summit undoubted evidence that it had been climbed five days previously by Mr. James de Salis. I have not been able to consult Mr. Whitehouse's original article, but from the reference given it is probable that to these gentlemen should be given credit for the first actual ascent, the first, at least, of which an account has been published.

On the 26th of April, 1890, the ascent was essayed by Prof. Angelo Heilprin, and Mr. Frank C. Baker, members of an expedition organized under the auspices of the Academy of Natural Sciences of Philadelphia.† Their route was taken from Ameca and their ascent followed the usual route along the margin of the glacier, the latter being named by Heilprin, Porfirio Diaz Glacier. They climbed to a point which was estimated to be about 75 yards below the summit, but here two impassable crevices, cutting directly across the crest of the mountain, prevented further progress. The height of this point they determined by aneroid barometer to be 16,730 feet.

Heilprin states in his account that the earliest recorded ascent of the mountain, so far as he was able to determine, had been made by a resident of Miraflores—Selis (?) by name—in November of the previous year. It is doubtful, however, whether much credence should be given to these reports.

Both of my guides informed me that they had been to the top, but a little acquaintance with them showed me that their statement, like many which they made, was to be taken with a considerable degree of allowance.

Other residents of Ameca or the City of Mexico told me of others who had ascended the mountain, especially two Englishmen, John-son brothers, residents of Miraflores, who had gained the summit by a route somewhat different from that usually taken. As this information was, however, of a hearsay character, I was unable to give it much credence.

---

*Vol. VIII, No. 3, p. 304, September, 1896.

†*Op. cit.* p. 258.

The ascent of Ixtaccihuatl seems, therefore, pretty generally to have foiled those who have attempted it.

While the difficulties are without doubt great, my own observations lead me to conclude that the failures have been due to lack of suitable preparation rather than to the absolute impracticability of the undertaking. Two parties have failed because their ascent was made in April, when severe snow storms descend upon the mountain. Hence, one of the winter months, such as January or February, should be chosen. Other parties have failed for lack of suitable means to cross the crevasses and treacherous ice surfaces. To overcome these obstacles, rope ladders, foot swaths and guide ropes should be taken, and all the precautions found necessary in Alpine climbing be observed. The party should also be provisioned so as to be able to spend a week if necessary on the slope of the mountain. Thus prepared, if the course of ascent is checked in one direction it can be undertaken in another, and by three or four trials the possibility or otherwise of reaching the summit can be demonstrated. The difficulties of the climb are, of course, greatly increased by the severe cold and rarefaction of the air, but that these alone would not prevent reaching the summit is shown by the many successful ascents of Popocatepetl.

It is desirable that further ascents of the mountain should be made in order to definitely determine its height. As the following table will show, there exist at present great discrepancies in the values obtained for this, and the differences are the more tantalizing from the fact that the probabilities of accuracy seem about equal for the two sets of values. According to Humboldt and Lenk the altitude of the mountain is less than 16,000 feet; according to Sonntag and Heilprin it is fully 17,000. The measurements of both Humboldt and Sonntag were trigonometric, and their work in other respects is of a character to warrant the highest confidence. Yet, though their determinations of the altitude of Popocatepetl differ only about 70 feet, those of Ixtaccihuatl have a variance of nearly 1,400 feet. Heilprin warmly supports Sonntag's value, both on account of his own barometric results and from the fact that, to the eye, as he states, Ixtaccihuatl appears as high as Popocatepetl, many persons even affirming that the former is the more elevated.

On the other hand, Lenk is positive that Sonntag's determination is incorrect. He states that from the point on Ixtaccihuatl reached by him, which he estimated as only 500 feet below the summit, he positively determined with a hand level that he had not, by some distance, yet reached the height of the Pico del Fraile on Popocatepetl. The altitude of this peak, by Sonntag's own determination, is only 16,570 feet (5,050.1 m.).

It is evident that until further determinations can be made the question as to the height of Ixtaccihuatl must be left undecided, though the writer is inclined to accept the higher altitude as probably the more nearly correct one. It is to be hoped that with modern facilities an attempt at ascent may soon be made which will prove successful in fixing this important datum.

TABLE OF DETERMINATIONS OF ALTITUDES ON IXTACCIHUATL.

	METERS.	FEET.	
Northern Peak (*La Cabeza*)	4,595	15,076	Saussure.
	5,080.9	16,670	Sonntag, 1857.
Middle Peak (*La Panza* or *Pico Mayor*)	4,785	15,699	Humboldt, 1803. Trig. Meas.
	4,816	15,861	Felix and Lenk, 1894, 500 feet estimated.
	5,168	16,958	Heilprin, 1890, 225 feet estimated.
	5,205	17,076.9	Sonntag, 1857, Trig. Meas.
	5,326.6	17,476	Almazan.
Southern Peak (*Los Pies*)	4,512	14,803	Saussure.
	4,516	14,817	Sonneschmidt, 1770.
	5,077.3	16,658	Sonntag, 1857.

While Ixtaccihuatl is usually spoken of as a volcano, I am inclined to agree with other writers* that it may be incorrect to apply this term to the mountain. I am aware that this is a much disputed point, but I am not convinced that any explorations have thus far proved the existence of a localized center where volcanic activity took place, or have shown that the mountain possesses the pericentric character which belongs to the true volcano. Sonntag states† that the appearance of the northern side of the mountain favors the hypothesis that there has formerly been a crater between the middle and northern peaks, the walls of which are now broken down and have filled up the cavity, but he was not able to approach near enough to verify his opinion.

Whitehouse,‡ who made an ascent November 9, 1889, says that "the crater, although entirely filled with ice and snow, is clearly distinguishable, forming a cup with gently sloping sides between the three almost equally high summits."

---

*O. H. Howarth, Geographical Journal, Vol. VIII, No. 2, p. 140.

†*Op. cit.* p. 60.

‡Ref. in the Geographical Journal, Sept. 1896, p. 305.

Pieschel* also observed what he believed to be a crater rim on the southeast flank of the mountain. As his opinion was based only on the appearance it presented as seen from Cholula, however, it can not be said to rest on very conclusive evidence. He also quotes from Humboldt a tradition of the Aztecs that the mountain at one time emitted smoke and ashes, but this is hardly satisfactory testimony.

With regard to the areas of volcanic sand which occur upon the mountain, all observers agree that their source was probably Popocatepetl, since, on account of its proximity, a favorable wind would easily spread the sands over the slopes of Ixtaccihuatl. These volcanic products are, moreover, more numerous at the southern end, which is what might be expected if they came from Popocatepetl. This absence of any volcanic products originating in the mountain itself, the absence of any well-defined crater, at least so far as proved, the strikingly elongated form of the mountain, the prismatic columns which jut out all over its slopes, the homogeneous character of its component rock and its coarse texture—all favor the supposition that the mountain may never have been, in any true sense of the word, a volcano, but originated as a great fissure eruption. The course of this fissure was obviously that of the Sierra of which it forms a part, and had the same direction as that which gave a partial vent to the lava and ashes of Popocatepetl. It can hardly be doubted also that the eruption took place prior to the formation of Popocatepetl.

Heilprin states† that the mountain gives evidence of having been at one time much more elevated than it is to-day. What this evidence is, however, he does not indicate.

The writer's trip to Ixtaccihuatl was made February 21–22, immediately after return from Popocatepetl. Horses and guides were procured at Ameca as before, and the party consisted besides myself of one mounted guide or *caballero*, and two Indian guides on foot. A pack mule was also taken to carry provisions and utensils.

The route followed was essentially that indicated on Sonntag's map, Pl. XVIII, it being the trail made by the *neveros* or ice collectors who cut ice at the glacier and bring it down by mules to Ameca. The trail is also used by the *rancheros* who live on the ranches scattered here and there over the flanks of the mountain, for bringing their products to market. After crossing the level plain on which Ameca is situated, the trail ascends rapidly, and the route is much steeper, comparatively, than that which leads up Popocatepetl. The brilliant and varied flora, picturesque barrancas and beautiful cascades lend everywhere a charm to the scene which contrasts favorably with the somber monotony which characterizes the route by which Popocatepetl is ascended. The greater fertility of soil and the more copious supply of water are probably the causes which combine to give the slopes of Ixtaccihuatl a more abundant and varied flora than those of its companion. The volcanic ashes which largely cover Popocatepetl both absorb the waters from the melting of the snow and hinder the growth of vegetation. Baker asserts* that the fauna and flora of the two mountains are exactly alike, but my own observations agree with those of Sonntag in considering the flora, at least of Ixtaccihuatl, to be much richer in comparison. The succession of zones, however, as marked by the forest growth, is quite similar on the two mountains. There were practically three of these noted, the lowest consisting of laurels, pines and cedars, the middle of spruces and firs, and the highest of pines. These latter grow more stunted till the limit of aborescent vegetation is reached at a height given by Lenk as 4,000m. (13,123 feet). The slopes of the mountain are cultivated to a considerable height, the ranch of Coraltitla being situated at an altitude of 3,310m. (10,860 feet). The smooth, green fields of these ranches, interspersed among the forest growth, lend a pleasing variety to the scene. The lower flanks of the mountains, except where they are cut into barrancas by descending mountain streams, are covered everywhere with soil, so that it is only rarely that one finds a rock exposure, or even loose bowlders. Wherever these could be found the rock showed remarkable uniformity. Everywhere it was the same amphibole-andesite, containing porphyritic feldspars 6 to 8mm. in length. In color the rock varies from gray to red, according to the state of oxidation of the iron. Such a homogeneity of rock over so wide an area is remarkable, and favors the view that the mountain originated as a fissure eruption rather than as a volcano. It is also remarkable that the rock should differ so completely in character from that of Popocatepetl. Near the southern end of the mountain Lenk found a rock which resembled that of Popocatepetl, in having the hornblende replaced by hypersthene. This seems to represent a transition stage, but the rock mass of the two mountains differs in a marked degree in its constituency.

---

*Zeitschr. f. allg. Erdkunde, Bund. V, p. 190.

†*Op. cit.* p. 258.

Another feature prominently noticed in ascending Ixtaccihuatl was the comb-like or aiguille-like character of many of its spurs. These usually took the form of ridges extending in a direction at right angles to the course of the mountain, and presenting on the western slope of the mountain bold escarpments to the west. The face of these escarpments was well-nigh vertical and strongly pillared, showing the columnar structure so characteristic of basaltic outflows. On the view given in Pl. XIV, a number of these escarpments may be traced on the flanks of the mountain. They apparently mark the course of outflows of eruptive rock of high viscosity, which, owing to this property, solidified before becoming much distributed. The surface relief of the flows has, of course, since been modified to a considerable extent by erosion.

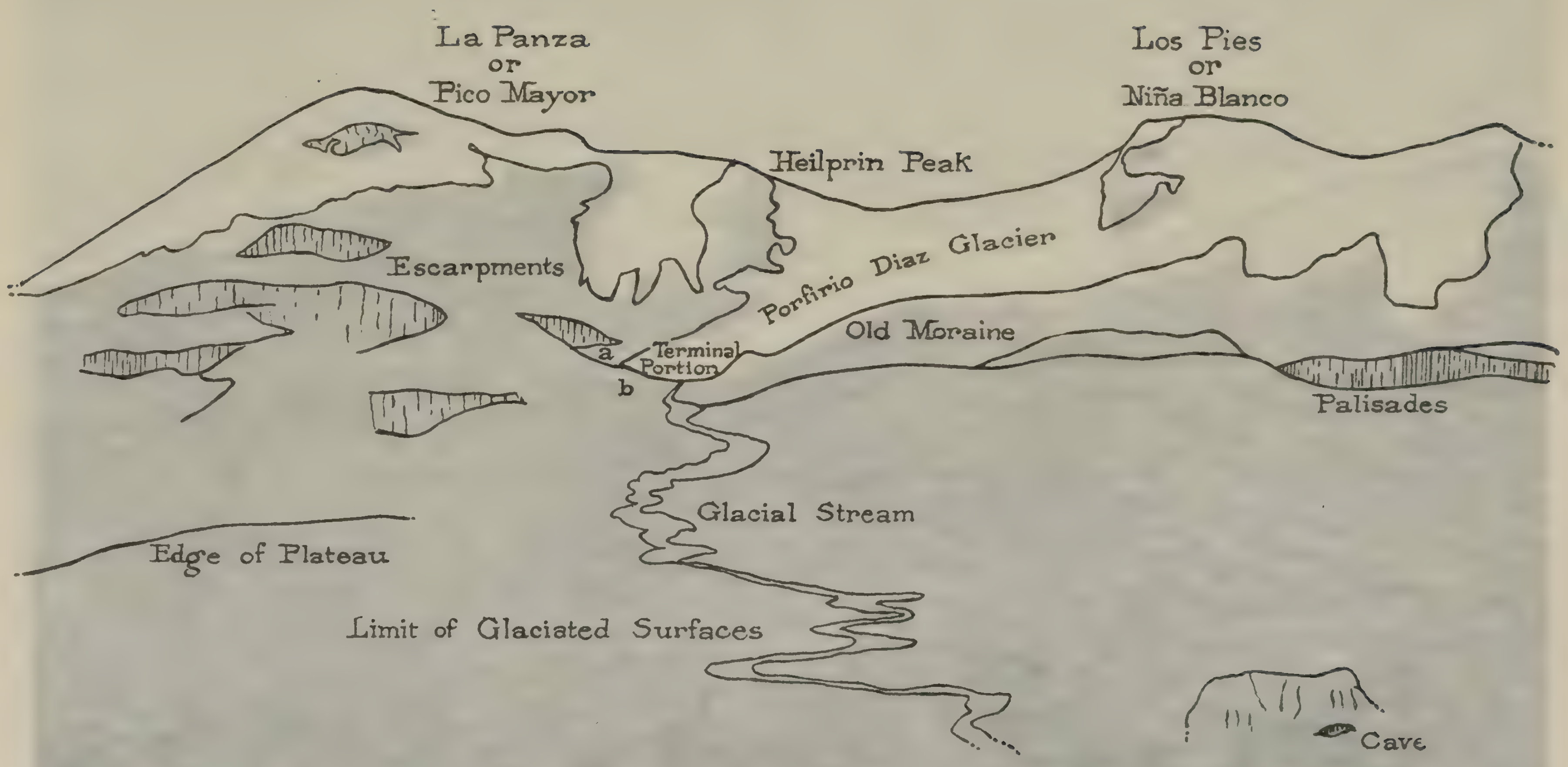
---

*A Naturalist in Mexico, p. 110.

The structure of many of these ridges shows that they were formed by successive outflows of lava. Layers of scoriaceous rock alternate with breccias and rock of a more dense, compact character. Occasionally the scoriaceous layer could be seen to have been consolidated into a breccia by the subsequent superposed flow. This was finely exhibited in the ridge from which the view shown in Pl. XIV was taken, the general rock structure being quite similar to that observed on Popocatepetl. Another feature noticeable in this vicinity was that of several caves in the rocks, which may have originated as bubbles formed by the imprisoning of steam or vapors when the rock was still in a molten condition, but more probably were formed by the weathering out of a more easily decomposable stratum. They at present furnish shelter for cattle and for travelers making an ascent of the mountain.

In one of these our party spent the night. The cave was reached about 5 P. M., the ascent from Ameca having consumed a little more than seven hours. Here the night was spent with as much comfort as possible, but after the going down of the sun the cold and wind were so severe that in spite of the protection of several blankets sleep was practically impossible. The next morning the ascent was continued on horseback to the foot of the glacier, which was reached in about an hour. It was no part of my purpose to attempt to ascend the mountain, so no effort of this sort was made. All the time at command was devoted to observation of the features of the glacier, the results of which follow. The time permitted for these observations was much less than could have been desired, but sufficient to observe the main features of the glacier.

Shortly after noon a driving, blinding snowstorm descended upon the mountain, preventing further observation, and compelling myself and guides to return to the camp as quickly as possible. As provisions were not at hand to enable us to spend another night on the mountain, return was made to Ameca, which was reached without mishap about dusk.



a. Point of view for Pl. XVII.
b. Point of view for Pl. XV.

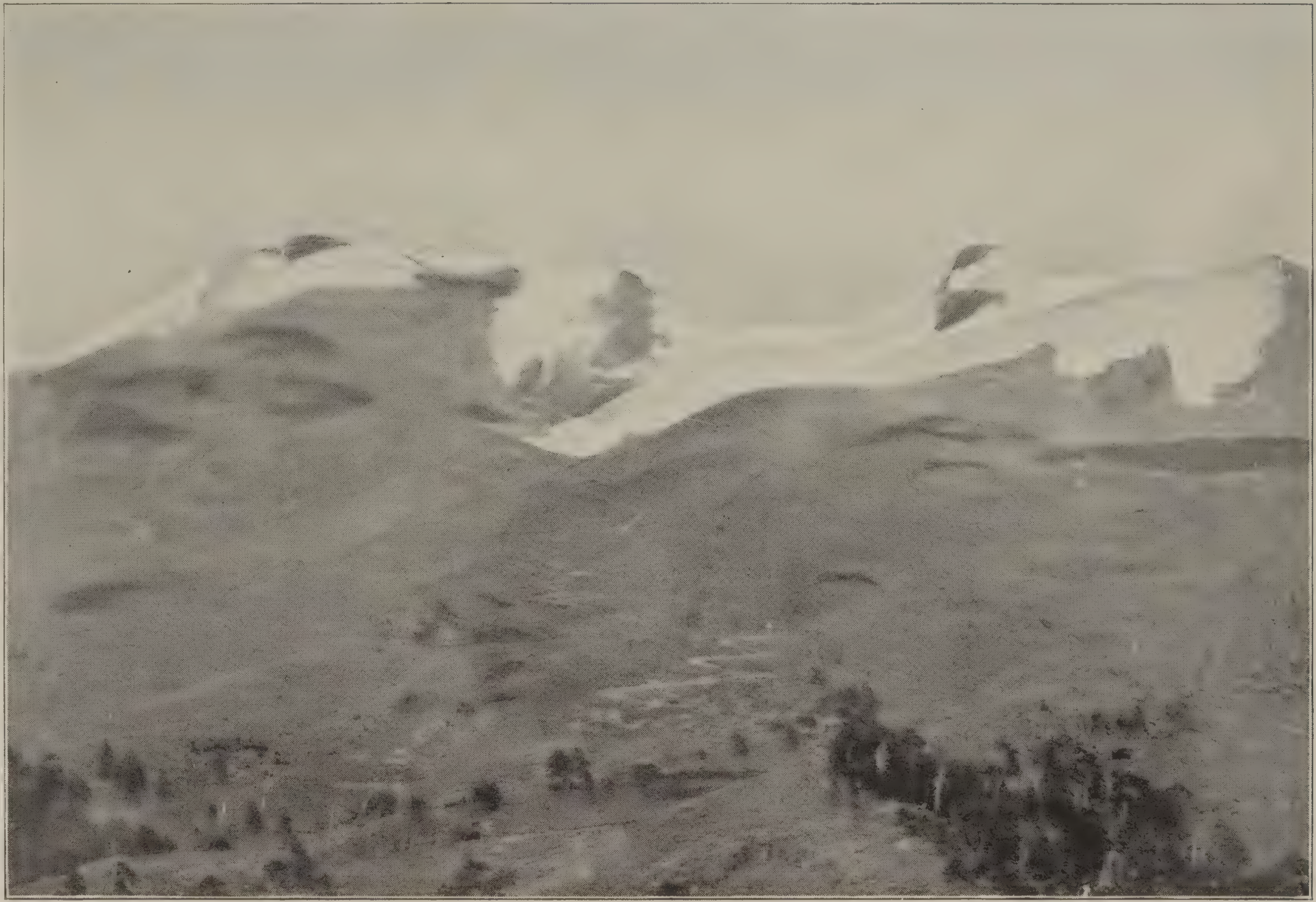


Photo. by the Author. Middle Peak. Southern Peak.

Middle and Southern Peaks of Ixtaccihuatl, from near Upper Limit of Trees, showing Porfirio Diaz Glacier.

PORFIRIO DIAZ GLACIER.

The first published mention of this glacier, of which I am aware, is made by Felix and Lenk in their work already cited, the latter traveler having crossed it in his attempt to ascend the mountain. Its various features convinced him that it was an actual glacier, though he could find none of the characteristic scoured and scratched surfaces, which usually accompany a moving body of ice. His observations, which are but meager, are given in the work cited.

Heilprin and Baker visited the glacier in 1890 in their attempt to ascend the mountain, and Heilprin, in his report,* proposes the name of Porfirio Diaz Glacier for one of several glacial streams (*sic*) which descend the slopes to a depth of 14,500 feet. He gives no further description of the glacier. Baker, however,† states that glacial tables and moraines were noted by the party. I know of no other published description of the glacier, nor does the fact of its existence seem to be generally appreciated. Many well-informed residents of the City of Mexico I found inclined to doubt the existence of a glacier on the mountain, and even to consider it impossible. Packard, writing in 1886,‡ states that the snow-fields of Ixtaccihuatl, which extend along the western side of the range, are, without doubt, thin like those of Popocatepetl, and give rise to no extensive glaciers. It was, therefore, partly to determine for myself whether a glacier existed on the mountain, that I resolved to visit the spot where it was said to be located.

My observations enable me to assert with certainty (1) that one exemplary glacier exists on the western slope of Ixtaccihuatl, and (2) that it formerly had a much greater extent than now.

Like Popocatepetl, the whole upper part of Ixtaccihuatl is covered with perpetual snow. The snow line marks on an average a zone about 2,000 feet below the summit of the mountain, but is, of course, several hundred feet lower during the summer or rainy season than during the winter or dry season.

While on Popocatepetl, however, the smooth surface of its conical summit affords no depression where snow and ice can accumulate—and such accumulation is further hindered by the porous, ashen bed on which the snow lies—the upper portion of Ixtaccihuatl is furrowed by several great valleys which by their form and character of the rock bed favor the formation of glaciers. These valleys have in gen-

---

*[*Op. cit.* p. 259.

†*Op. cit.* p. 115.

‡*Op. cit.* p. 121.

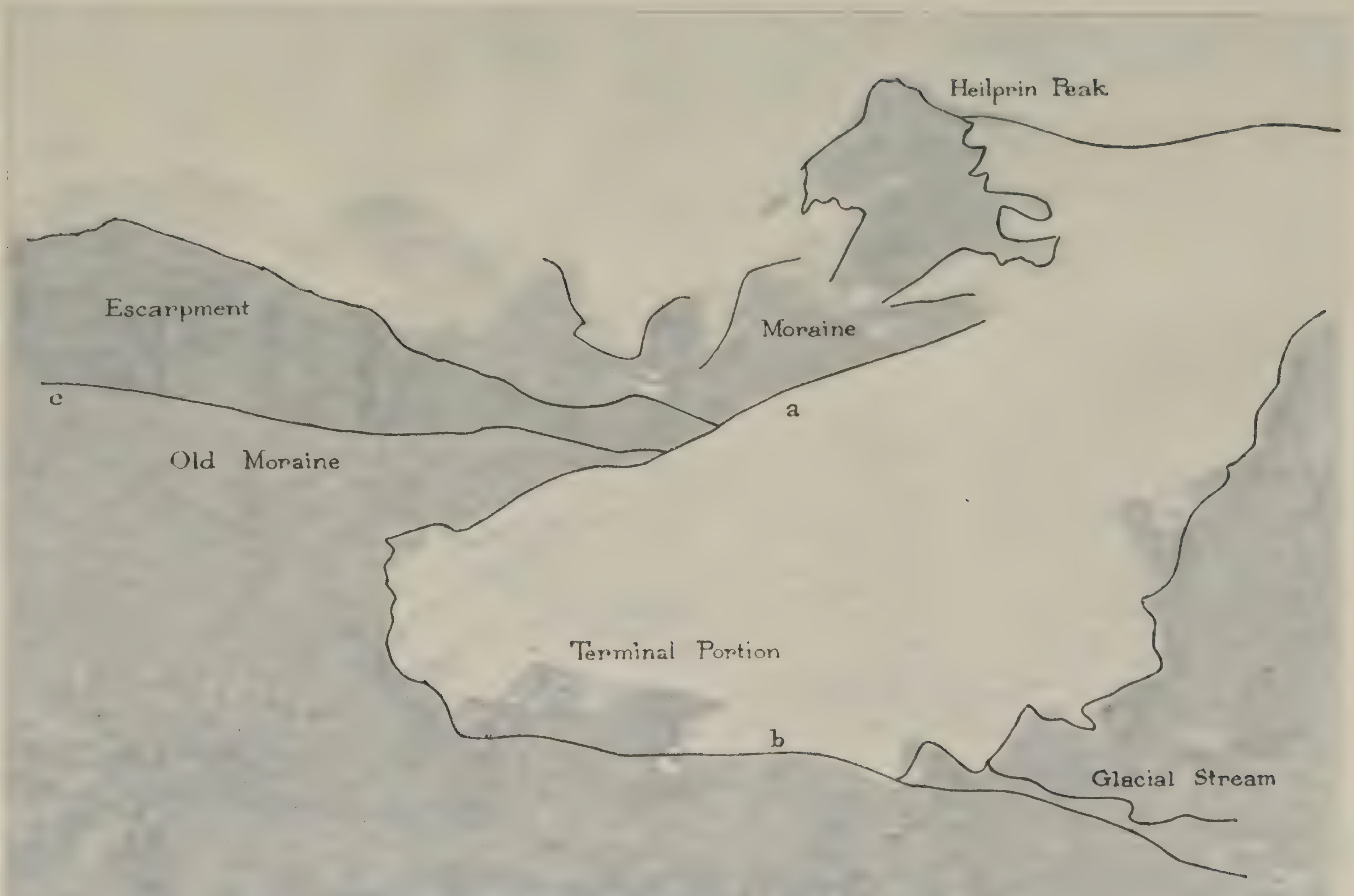
eral a course transverse to that of the mountain, and cut into its eastern and western slopes. Whether glaciers descend several of these, as Heilprin states, I do not know, but it seems not improbable. Some of the residents of the region, however, though they knew of the one *ventisquero*, as they call a glacier, *i. e.*, the one visited by me, were quite sure that it was the only one.

The glacier named by Heilprin, Porfirio Diaz Glacier, fills the valley lying on the northwest of the mountain between the central and southern peaks. Its upper portion lies in a saddle-shaped depression about three-fourths of a mile wide. The valley then narrows and descends in a direction west-northwest to a well-marked terrace which skirts the western slope of the mountain a few hundred feet below the snow line.

Judging from the slope of the snow field, the average slope of the valley is about 30°, but it is somewhat steeper in the lower part. Tributary to this main valley another lies between it and the central peak, separated from the main valley by a small spur of the mountain, which I propose to call Heilprin Peak. The slope of this valley is much greater than that of the main ice trough, being often as great as 45°.

COLLECTING GROUND OF THE GLACIER. These two valleys constitute the collecting ground of the glacier, and the narrowed prolongation of the main valley forms the trough wherein lie the middle and lower parts of its course. The glacier, therefore, is of the broad, Alpine type. Its greatest length from the main ridge to the terminal moraine can not be more than one and one-half miles; a course so short that one would doubt the possibility of an ice-flow were it not proved by other evidences.

From only three exposed peaks can the glacier gather moraine material; these are the southern and Heilprin peaks, and the southern slope of the central peak. Owing to the limited source of supply and the short course of the glacier, the formation of well-marked lateral moraines does not take place. The nearest approach to anything of this sort was seen in a number of bowlders showing something of a lineal arrangement, which lay at the time of the writer's visit at the base of the southern peak. About the base of Heilprin peak also, lay an extensive deposit of clay and bowlders. This material is not carried out into the main body of the glacier as one would suppose from the course of the valley, but is crowded off to the northern side where it is distributed along the foot of a cliff extending in the direction of the glacier. I am not sure but the ice mass between Heilprin peak and the central peak should be considered a



a. Point of view for Pl. XVI.
b. A *Nevero* or ice cutter.
c. Point of view for Pl. XVII.

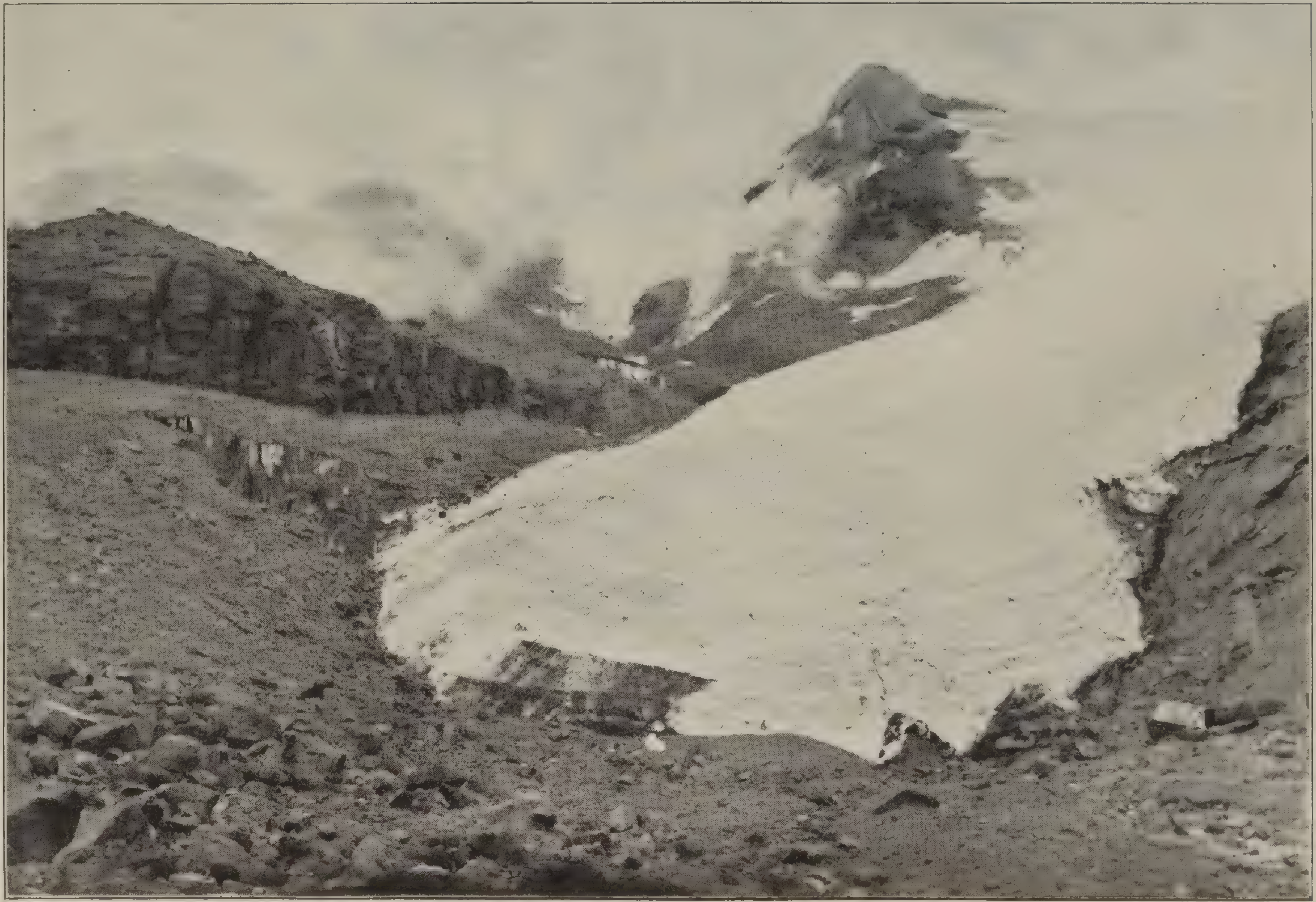


Photo. by the Author.

PORFIRIO DIAZ GLACIER FROM OLD TERMINAL MORAINE.

glacier of the second order, the terminal moraine of which is the deposit which I have mentioned, instead of being regarded as tributary to the main glacier. At times, however, without doubt, this portion of the glacier joins the main body.

MIDDLE COURSE OF THE GLACIER. Though lateral moraines are wanting, there is no lack of evidence that the glacier is a true ice stream constantly bearing and depositing debris. Scattered promiscuously over the surface of the terminal portion of the glacier lie bowlders of all sizes, as well as other varieties of rock debris which could have reached their positions only by being transported by the ice.

The fact is illustrated in Pl. XVI, a view taken on the surface of the glacier several hundred yards from its terminus and about 200 feet south of the northern border. The point at which the photograph was taken is indicated at *a*, Pl. XV. The great bowlders here shown must have floated to their position on the ice stream. Other features common to the middle course of glaciers could well be seen in this vicinity. There were glacial tables formed by bowlders sometimes several cubic feet in dimension, resting on pillars of ice 12 to 18 inches in height; sand cones 2 to 5 feet in height and ridges similarly formed 20 or 30 feet in length. As is well known, and as the different stages of formation well showed, these various phenomena have their origin in the protection from melting furnished to the ice by the sand or bowlders above it, which brings the latter into relief as the adjacent ice melts away.

The surface of the ice was nowhere strongly crevassed. The crevasses which existed were irregular and short, few being over 30 feet in length. All that were observed had a course transverse to that of the glacier, and thus, as might be expected, no well marked séracs were formed. The fantastic, pinnacled shapes assumed by the upper surface of the ice, illustrated in Pl. XVI, indicate, however, a certain amount of longitudinal fracturing.

It was of interest to note the gathering of surface bowlders by the crevasses causing them to lie in rows across the field of ice. This formation was produced by the more rapid melting of one wall of the crevasse than the other, forming a long slope, which dipped toward the other nearly perpendicular wall. Along this the freed bowlders slid to the crevasse as illustrated in Fig. 2, and so were gathered in rows following its direction. The sloping side was usually the eastern. I am of the opinion that some of the minor bowlder trains found lying transverse to the direction of glacial movement in the glaciated regions of our own country may have had a similar origin, since the retreat of the ice would leave them in the position occupied by the crevasse.

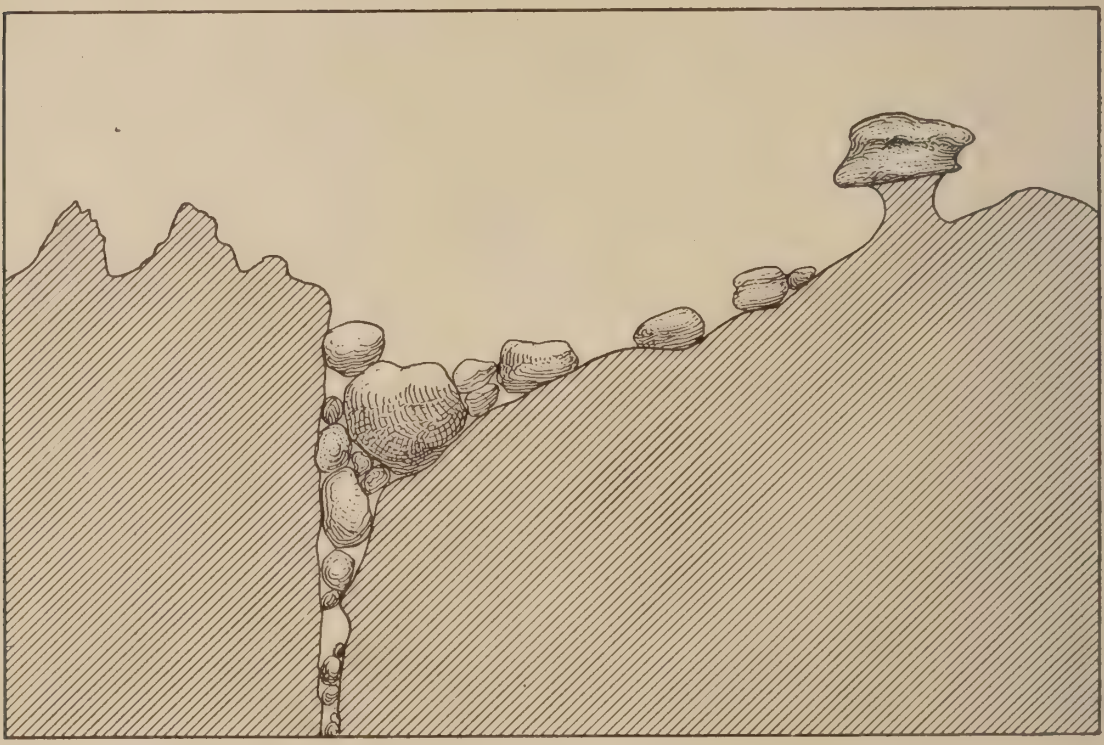


FIG. 2. GATHERING OF BOWLDERS BY A CREVASSE, PORFIRIO DIAZ GLACIER.
Sketched by the Author.

TERMINAL PORTION OF THE GLACIER. This is shown in Pl. XV which looks up the glacier from a point about half a mile below. Nearly the whole course of the glacier is shown, Heilprin peak being in the middle background. The upper part of the mountain is hidden by clouds, which were fast descending when the photograph was taken. Outlined against the surface of the ice in the middle foreground is the figure of a man, one of the *neveros* or ice collectors who make a business of conveying the ice to the market at Ameca. His form will give an idea of the size of the features shown. The termination of the glacier shows a fanning out of the ice tongue and a convex surface such as is typical of a glacier terminus. From the border the ice ascended in a series of steps sufficiently well marked to be used by the *neveros* as planes for cutting. These steps were cut through here and there by cross fractures or longitudinal crevasses evidently caused by the bulging and spreading of the ice as it debouched into the broader part of the valley. At the top of the ice tongue a massing of the debris could be seen which indicated its collection in the central portion of the valley trough by the onward movement of the glacier.

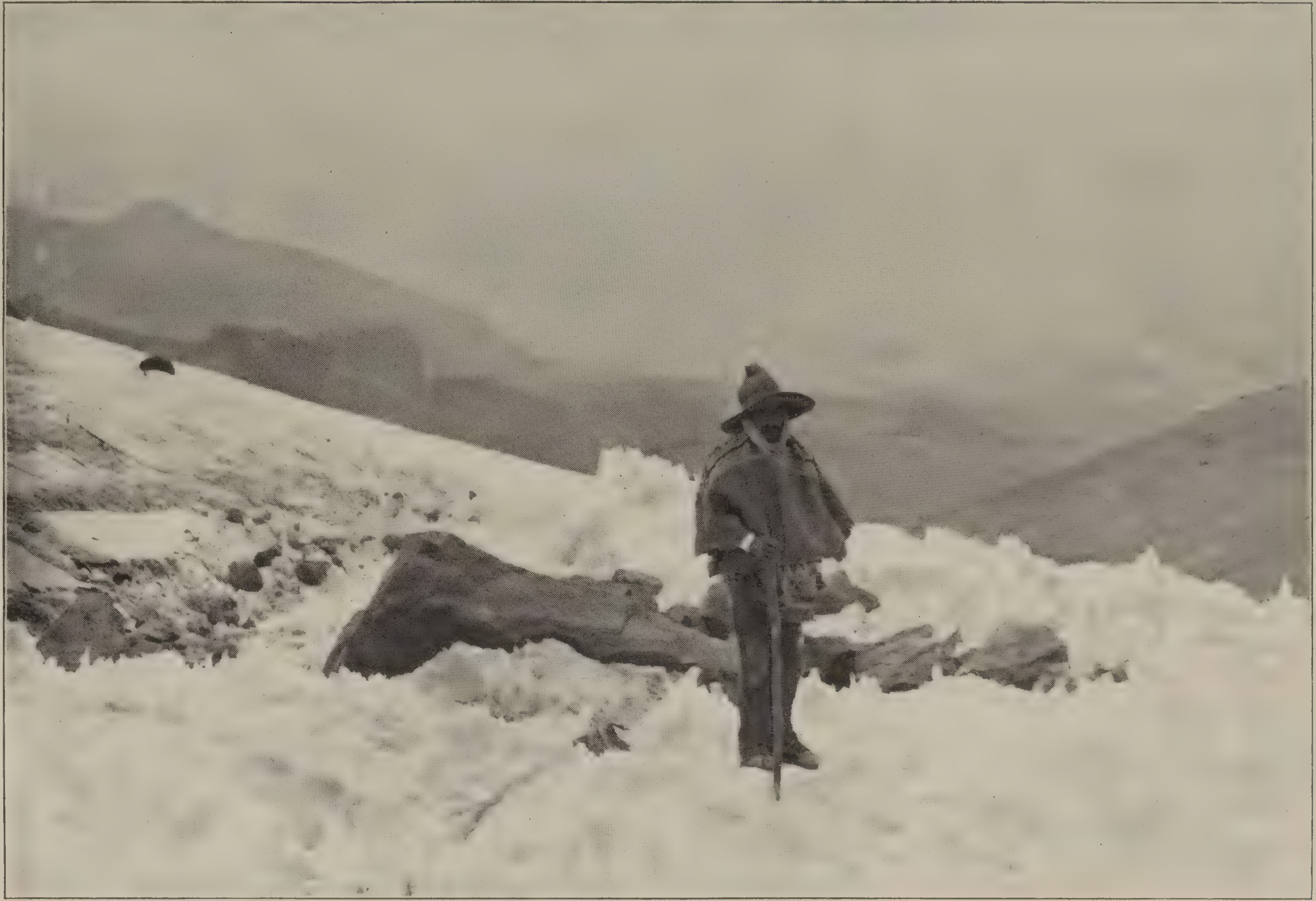


Photo. by the Author.

SURFACE OF PORFIRIO DIAZ GLACIER.

TERMINAL MORAINE. Immediately in front of the ice lay a small ridge of detritus, making a bank for the muddy torrent which ran out from beneath the ice, but there was no large mass of drift. From the foot of the glacier westward the valley was strewn for a distance of several hundred yards with an irregular accumulation of bowlders, and sand, resulting from the decomposition of the latter. A peculiarity of the drift was the extremely friable character of many of its constituent pebbles and bowlders. Though appearing hard and tough externally, they crumbled into powder at a stroke of the hammer. Apparently their passage in the glacier had caused them to suffer rapid decomposition, an action favored by the coarse, porphyritic structure of the rock. The material of the drift was uniform in character with that of the component rock of the mountain, a coarse, porphyritic amphibole-andesite. There was some variation in color from black to red or paler, according to the degree of oxidation of the iron, but the structure and constituents of the rock were everywhere similar. Very many of the bowlders, especially the larger ones, showed smoothed and scored surfaces and rounding of the solid angles. This it is important to note because Felix and Lenk in their observations on the glacier state that they did not find scored and scratched surfaces. It is not easy to understand how they could have overlooked these, for not only most of these bowlders but those of the old lateral moraines and many rock surfaces farther down the mountain side showed distinct smoothing and scoring from glacial action.

The debris for the distance mentioned, lay about evenly distributed, there being no ridges which indicated stages of retreat or advance by the glacier. At a distance of about a quarter of a mile from the foot, however, the material rose to a somewhat ridge-like form and terminated, making a distinct barrier across the valley as seen from below. This I consider to represent the terminal moraine of the stage of the glacier which formed the old lateral moraines to be described later. It has been cut through by the stream flowing out from the present glacier and its form and arrangement have thereby been much changed, but its general connection with the lateral moraines was apparent at a glance. Since between this moraine and the present foot of the glacier only a bare, stony tract intervenes, having no well-marked ridges of debris, it may be assumed that the glacier is at present retreating. No opportunities for positive determination of this could, however, be gained in so short a time for observation.

EVIDENCES OF FORMER EXTENT OF THE GLACIER. *a*. OLD LATERAL MORAINES. To the north and south and somewhat west of the foot of the present glacier, converging in their course toward the mouth of the valley, lie two great ridges of debris, which from their form and the character of the material of which they are composed, appear to be old lateral moraines. Their position is indicated in Pl. XV. Pl. XVII is a nearer view of the northern moraine taken from the point marked *c* in Pl. XV. The point of view is the crest of the smaller ridge of the two into which the northern moraine is divided and the view looks westward along the ridge course. While the southern moraine was not submitted to close inspection, it appeared from a distance to be a counterpart of its northern companion. Of the northern moraine (for, as has been said, there are properly two ridges of drift lying side by side), the largest or one farthest from the glacier, is about one-third of a mile in length and maintains a height of about 60 feet above the slope of the mountain. The inner one is shorter and less than one half the height of the other, but in other respects similar to it. It is separated from it by a sharply-defined trough such as to show that the ridges are distinct in origin. The sides of these ridges slope at a uniform angle of from 30° to 40°, being as steep as the angle of rest will, for the debris of which they are composed, permit. This is made evident when one attempts to climb the slope of the moraine, for every step brings down a shower of stones and sand. The upper surface of the ridge is nearly level and its edge sharp. The size of the bowlders poised on the crest of the ridge or upon one another, and their delicate adjustment of position all over the moraine indicate that they were left in place by the melting of the ice beneath them. No assortment of the debris, such as might be expected from the rolling of the coarser bowlders to the bottom has yet taken place, nor is any stratification apparent. All the material lies in an unassorted condition. It seems proper, therefore, to regard these moraines as of comparatively recent origin. A large proportion of the bowlders examined on both moraines were distinctly rounded, scored and smoothed, and gave positive evidence of having been subjected to glacial action. This fact, together with the shape and extent of the ridges, stamps these positively as moraines of glacial origin and precludes the supposition of their being talus cones.

I believe the manner of their formation is similar to that now in progress at the base of the northern cliff as shown in Pl. XV. Here the debris brought down on the side of the glacier is spread out along the base of the cliff. Being thus protected, the ice underneath this earthy covering does not melt so rapidly as on the exposed surface of the glacier itself. At the contact of the two a trough is formed by

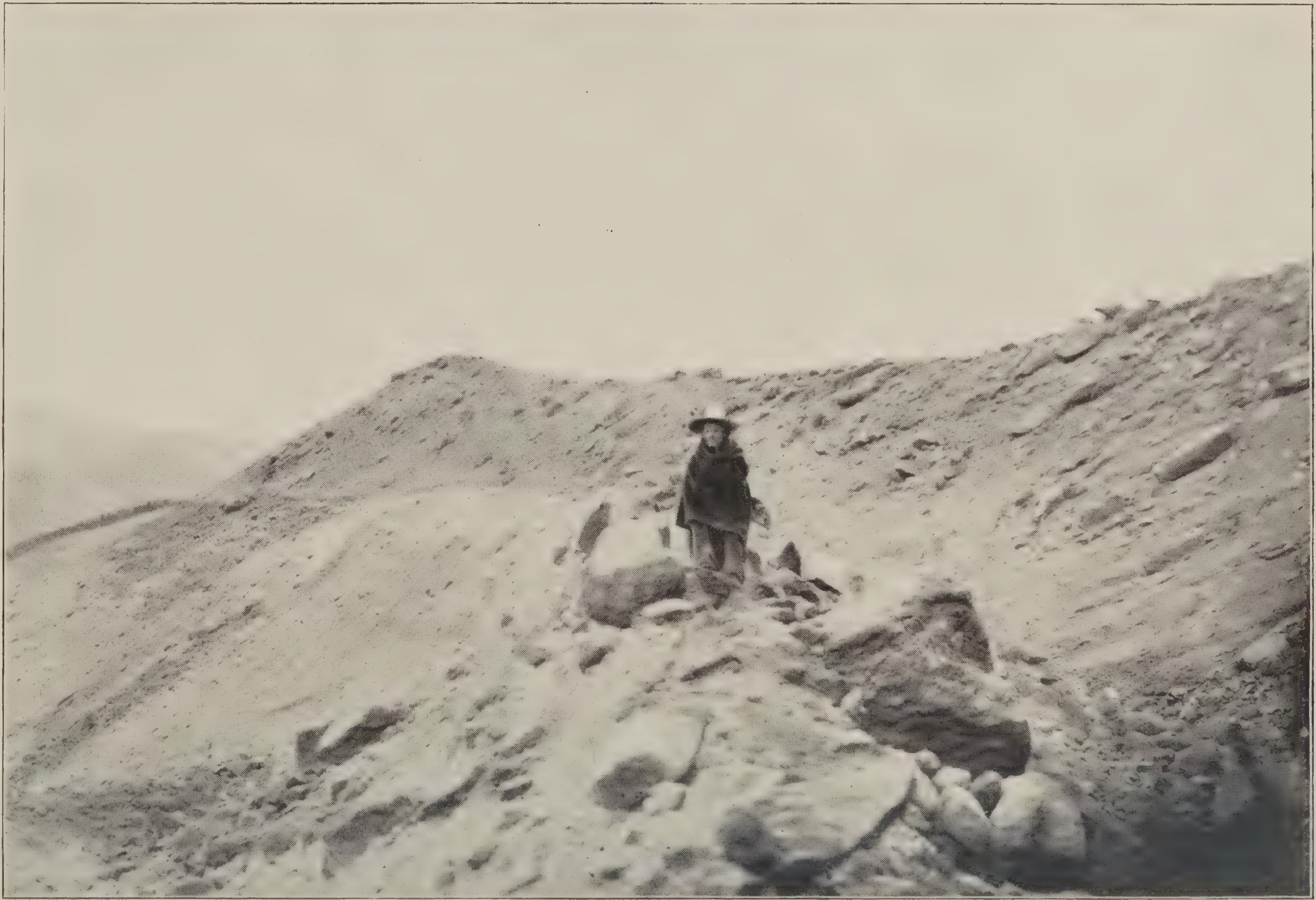


Photo. by the Author.

OLD MORAINES, PORFIRIO DIAZ GLACIER.

the drainage from both sides, and this naturally grows wider and deeper as long as the conditions remain the same. Thus a ridge of debris is piled up against the wall of the cliff, and its content is increased by every advance of the glacier.

It is evident that when such a formation takes place on an open surface, a double slope will be formed and thus will be produced moraines of the form already described.

There can be little doubt that the terminal moraine which I have mentioned as extending across the valley, as well as the ridge to the south marked "moraine" in Pl. XIV, was contemporaneous in origin with one of these lateral moraines. The material of the former, however, has been largely removed by glacial streams, so that the entrance to the valley lies comparatively open at the present time.

b. GLACIATED SURFACES ON THE MOUNTAIN SIDE. On the way up from the cave to the glacier, rock surfaces which plainly showed the marks of glacial action were everywhere in evidence. The first were seen about three miles below the glacier at the point indicated in Pl. XIV. From this point on they became more numerous and could be seen on every side. Projecting bosses of rock were smoothed, polished and striated on the sides and top, and the upper edges of nearly all the western escarpments were noticeably rounded. The striæ did not have great depth, nor did the rounding of the escarpments indicate that they had been subjected to great pressure, yet the evidences that the region had been covered by a glacier were unmistakable.

Just what was the extent of this glacier, I can not positively state. Upon Pl. XIV the point at which the first glaciated surfaces were noted is marked. Yet there were no evidences of drift at this point, nor in the vicinity. The ridge from which the view, Pl. XIV, was taken is one rising quite sharply from the slope of the mountain and running in an east and west direction.

If the glacier had extended below it, marks of glacial action should be left on the sides or top of the ridge. While I can not say that there is none such, none was noticed. The rather gentle slope of the ridge forming to the north one side of the valley, in contrast to the steep, rugged character of the southern slope suggests, however, that the former might have been one side of the valley through which the glacier flowed.

It may, therefore, be concluded that either the easy decomposability of the rocks left by the glacier on its retreat has caused them all to disappear, or that the greatest extent of the glacier may be found at a point farther down the mountain side than was observed by the writer.

INFERENCES REGARDING CLIMATE. From the evidences of earlier extension of the glacier beyond its present limits, certain inferences regarding former conditions of climate can be drawn which, while by no means positive, are at least pertinent. In the first place, the difference in size and distinctness in origin of the two older lateral moraines, indicates remarkable variations in climate as regards temperature or snow fall.

The conditions which produced these, could not have been those of gradual, constant return to a warmer climate, but rather a varying return, marked either by sudden renewal of former conditions, or by cyclical movements, the climax in cold or precipitation of which is represented by each moraine. The gap between the greatest extent of the glacier and the oldest lateral moraine, between this moraine and the younger one adjoining and between the latter and the present glacier limits points to a similar conclusion. It is easy to go farther and inquire whether the greatest extent of the glacier was not contemporaneous with the Glacial Period, and, therefore, that a lowering of temperature at that time for the whole globe, is indicated. As is well known, observations hitherto made in the Andes and Himalayas point to such a conclusion. It is interesting, therefore, to find that the evidence here corroborates such a view.

Before leaving this subject mention should be made of the view of Packard* that the entire region shows marks of glaciation. According to this author the mountains must have been covered with glaciers which descended to a point 9,000 feet above the sea, and about 1,000 feet above the present level of the plains. The low, rounded hills at the base of Popocatepetl he regards as of moraine origin, and from this point he observed moraines as far up as the snow line. He infers that the ice must have filled the valley or pass between Ixtaccihuatl and Popocatepetl, spreading out over the plateau like a *mer de glace* and sending glaciers down to the lakes then covering the plains of Anahuac.

While hesitating to differ from the opinion of so experienced an observer, I am unable to believe that evidences of so extensive glaciation as he reports can be found. So far as I could observe, there is no drift or moraine material to be seen on the lower slopes of either of the mountains. The absence of bowlders from the soil of these slopes is indeed remarkable, and indicates quite strongly that the soil is of stream and lake deposit in the lower slopes, while on the upper it is formed solely by the disintegration and decay of the underlying rocks. Almost the only bowlders to be observed in these regions are

---

**Op. cit.* p. 113.

those laid bare by the water courses. None of these, so far as I observed, showed glacial striæ or smoothing. The rounding of their solid angles was rather to be attributed to water. Most of the exposed rock surfaces, too, were rough and angular, showing none of the rounding and scoring which would be expected from glaciation. Again, the scored surfaces below Porfirio Diaz Glacier, as has been said, gave evidence of having been submitted to a comparatively gentle pressure, as if the glacier had nearly spent its force when it reached them, rather than having just begun its career. While confident, therefore, that the glaciers of the mountains had at one time a greater extent than now, I can hardly believe that they reached the proportion of the great *mer de glace* which Packard has pictured.

PETROGRAPHY.

The prevailing rock of Ixtaccihuatl is a compact amphibole-andesite of a gray color. In some areas it is porous and slag-like, and here, through oxidation of the iron, may become reddish in color. In structure it is porphyritic. The most prominent phenocrysts are white, lath-shaped crystals of plagioclase feldspar, some of which are from 6 to 8 mm. length. Under a lens distinct striations can be seen on many of the crystals, which mark them as plagioclase. Twins according to the Carlsbad law as well as trillings and fourlings, are not uncommon. The amphibole phenocrysts are less noticeable, but on close examination they are seen to be quite numerous. They are black, shining with the peculiar horn-like luster characteristic of this mineral, lath-shaped, and frequently attain a length of 3 or 4 mm. Distinguished by a dark-green color and sub-resinous luster, are also to be seen phenocrysts of pyroxene. These crystals are of stout, prismatic habit, showing the unit prism, pinacoids, and occasional pyramidal faces. They are more numerous in some portions of the rock than others, seeming at times to prevail in quantity over the amphibole.

Under the microscope the ground mass resolves into a carpet of microlites, showing the well-known hyalopilitic structure. The microlites are transparent, needle-like, .02 to .06 mm. in length. Scattered among these are opaque grains referable to iron oxide. The larger part of the ground mass remains dark during a complete rotation in parallel light, indicating a glassy base. Certain of the larger microlites by their inclined extinction and low interference colors are marked as feldspar. Less numerous are light-green grains (about .02 mm. in diam.) of a pyroxene. There is no well-marked flow structure such as is to be seen in the andesite of Popocatepetl.

Of the phenocrysts the feldspars are the largest and the most numerous. They have usually well-defined crystal outlines. Many of them show mechanical deformation from pressure. This is usually only evinced under crossed nicols, but when so seen great cracks traverse the crystals and varied angles of extinction are exhibited. Some crystals likewise show distinct zonal structure. The crystals are as a rule very free from inclusions, but some contain scattered augite microlites and others fluid inclusions.

Observations, according to Levy's method, of the angle of extinction of the lamellæ gave 30° as the greatest angle, thus determining the feldspar as labradorite. This determination was corroborated by the extinction of the Carlsbad twins which gave angles corresponding to labradorite of the composition Ab 3 An 4. The feldspar has been determined by Felix and Lenk* from its optical characters as bytownite, but by its specific gravity as labradorite. They account for this variance by the well-known fact that the peripheral portion of a feldspar showing zone structure is frequently richer in silica than the interior.

The hornblende crystals are of considerable size, some of the sections across the prism measuring 2 mm. Most of them are anhedral rather than idiomorphic and show much corrosion and resorption. Frequently the alteration has been such that the entire crystal has been replaced by iron oxide and indeterminate grains and scales. These constituents usually, however, possess a zonal arrangement and conform to the bounds of the original hornblende crystal.

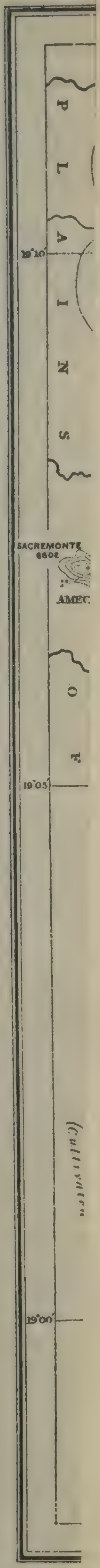
The pleochroism, $\mathfrak{a}$ greenish-yellow, $\mathfrak{c}$ dark-brown, is strongly marked, as well as the absorption $\mathfrak{c} \mathrel{\overline{>}} \mathfrak{b} > \mathfrak{a}$. The extinction parallel to the prism is sometimes as high as 17°.

Among other phenocrysts numerous hypersthene crystals are recognizable by their square or nearly circular outline when cut across the prism, as well as by their pleochroism, $\mathfrak{a}$, reddish-brown, $\mathfrak{c}$, olive green. They have an average diameter of about 0.7 mm.

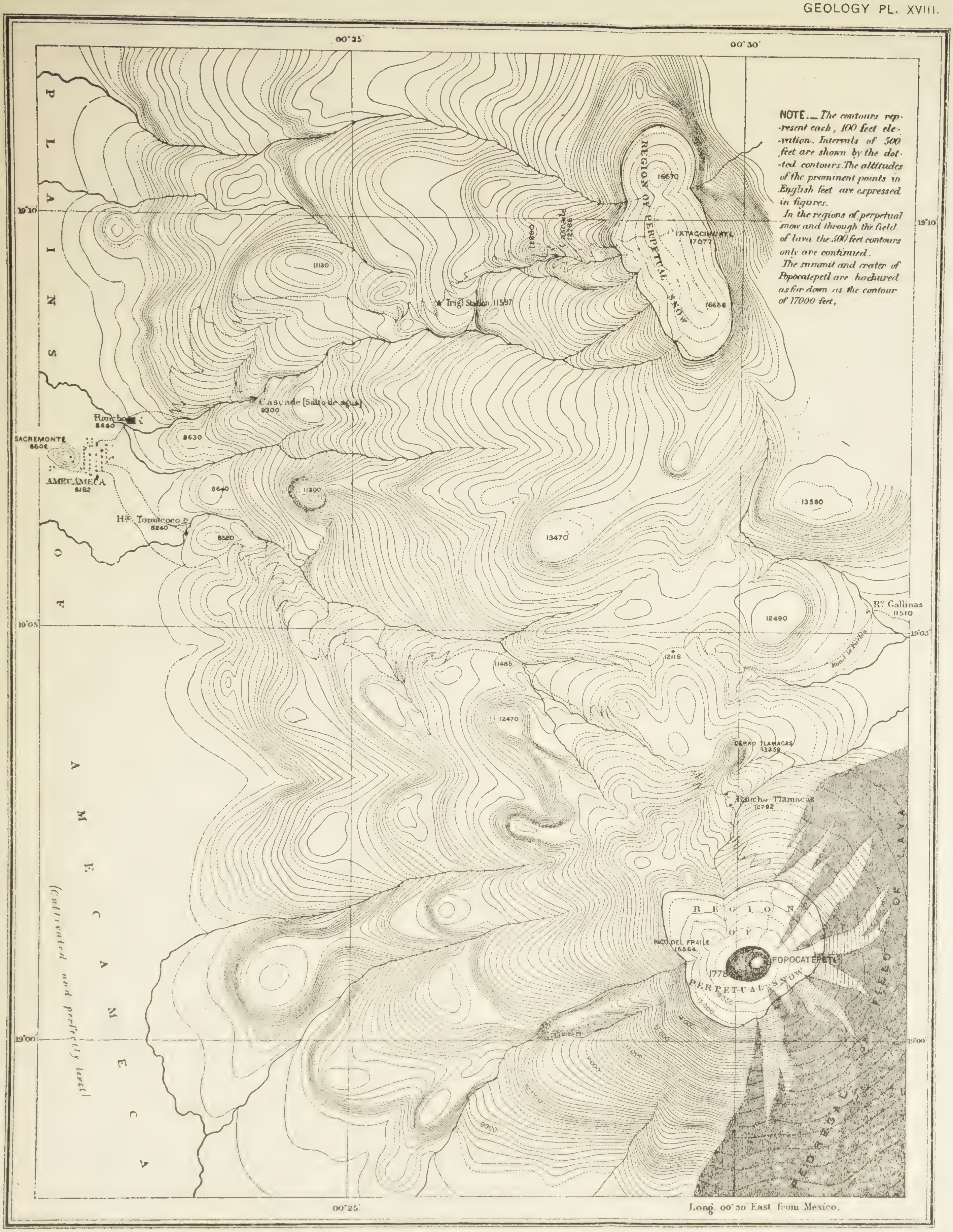
Less frequent are crystals of augite, which are larger and distinguishable by their color and prismatic cleavage.

Among accessory minerals may be noted needles of apatite 1 mm. in length with basal cleavage and frayed outlines. They contain fluid and gas inclusions. Magnetite crystals can also be observed.

***Op. cit.* p. 92.



Redu



NOTE.—*The contours represent each, 100 feet elevation. Intervals of 500 feet are shown by the dotted contours. The altitudes of the prominent points in English feet are expressed in figures.*

In the regions of perpetual snow and through the field of lava the 500 feet contours only are continued.

The summit and crater of Popocatepetl are hachured as far down as the contour of 17000 feet.

SCALE, $\frac{1}{130000}$.

CONTOUR MAP OF POPOCATEPETL, IXTACCIHUATL AND VICINITY.

Reduced from map by August Sonntag and Thomas Jekyll, scale $\frac{1}{100000}$, published in Smithsonian Contributions to Knowledge, Vol. XI.

FIELD COLUMBIAN MUSEUM
PUBLICATION 33.
GEOLOGICAL SERIES. VOL. I, NO. 3.

THE ORES OF COLOMBIA

From Mines in Operation in 1892.

BY

HENRY WINDSOR NICHOLS, S.B.
Assistant Curator of Department.

OLIVER CUMMINGS FARRINGTON, PH.D.
Curator of Department.

CHICAGO, U. S. A.
March, 1899.

TABLE OF CONTENTS.

Page.

INTRODUCTION, ... 125

PHYSICAL FEATURES AND GENERAL GEOLOGY, ... 128

THE MINING DISTRICTS AND ORES OF ANTIOQUIA, ... 130

- Remedios, ... 132
- Amalfi, ... 137
- Anori, ... 138
- Sta. Rosa Osos, ... 139
- San Pedro, ... 140
- W. Antioquia, ... 141
- Frontino, ... 141
- Anzá, ... 142
- Amaga, ... 143
- Titiribí, ... 144
- Zancudo Establishment, ... 145
- Caramantá, ... 151
- Marmato, ... 153
- Echandía, ... 153
- Supía, ... 155
- Manizales, ... 156

THE MINING DISTRICTS AND ORES OF TOLIMA, ... 159

- Soledad, ... 161
- Sucre, ... 161
- Santana, ... 162
- Guayabal, ... 163
- Frias, ... 163
- Libano, ... 165
- China River, ... 165
- Venadillo, ... 167
- Ibague, ... 167

THE MINING DISTRICTS OF PAMPLONA, ... 170

GENERAL CONCLUSIONS, ... 172

LITERATURE, ... 174

MAP, ... 177

INTRODUCTION.

The following pages describe a collection of ores, rocks and minerals which was prepared to illustrate the mineral resources of Colombia at the World's Columbian Exposition. The major part of the collection was afterwards donated to the Field Columbian Museum. It was prepared by F. Pereira Gamba, a mining engineer of Bogota. The scope of the collection is indicated by the title of the original catalogue, "Catalogue of the Mines in Actual Production in the Republic of Colombia." In an answer to an inquiry, Señor Gamba writes: "The collection sent by our government to the Columbian Exposition was entirely formed by me. I traveled throughout the country collecting the specimens and stones in such manner that there is not one specimen of ore or other rock which was not personally collected and examined by me, and I believe that the collection, as it was sent, is the most complete representation of our minerals and mineral wealth ever made. * * * It is not a show of chosen specimens, but a collection of the common ores that are mined here. * * * I sent specimens of all rocks interfering with the veins."

This collection merits attention for the light it throws upon the nearly unknown nature and mode of occurrence of the ores of one of the important gold-producing countries of the world. Gold was first mined by Europeans in Colombia in 1537, and during the sixteenth and seventeenth centuries it was the great gold producer of the world. It now ranks ninth among the gold-producing countries; for 1898 its production of gold has been estimated as 5,868.7 kilograms, or about one and one-third per cent. of the world's production for that year. During the last century and the early part of the present, accounts of the mineral resources of Colombia were given by Humboldt, Boussingault, Chevalier, and other travelers, and although later travelers have explored the country, they have paid but little attention to the geology and mining of the region. As a result the knowledge of this region has not kept pace with the general advance of geological knowledge, the advance made in our knowledge of ore deposits of late years and with the great changes in the science of lithology.

As an example, it may be mentioned that the local names now applied to the rocks of the mining regions of Colombia follow the loose classification of the time of Humboldt and Boussingault. The name granite, for instance, is applied to a dacite, and rhyolites, andesites, trachytes and their tuffs are known as porphyries and syenites.

The collection also merits attention in that it approaches much more nearly than is usual the ideal of what a collection in economic geology should be. Such collections are usually made by the selection of specimens of rich ore accompanied by any choice or rare minerals associated with them, and throw little or no light upon the nature or mode of occurrence of the deposits. This collection differs in important respects from such. There was little attempt to secure showy specimens, and Señor Gamba took great care to secure average ores and to collect specimens of the gangue, associated minerals and country rock. To truly represent the resources of a region it is not enough to have such selected specimens of ores and choice or rare minerals. An ideal collection should have specimens of each kind and grade of ore produced—of the gangue, of all associated minerals, of the country rock, of intrusives, and, in short, of all rocks and minerals which may be associated with the ores. These specimens should be so labeled that their relation to each other may be readily understood. The relation of the value of an ore deposit to its surroundings should also be shown when possible. For example, when a vein which is rich in igneous rock becomes poor in clastic material, or when the deposit is rich only in the vicinity of some intrusive rock, this may often be shown in the collection. Again, an ore may always be accompanied by some peculiar mineral, or may have some other easily recognized feature which may and should be shown in the collection. The classic instance of Dr. Jackson's discovery of the emery deposits of Chester from finding margarite, which he knew was accompanied by emery in Asia Minor, bears witness to the importance of a knowledge which may be imparted by collections made on the right plan. Besides the specimens, much information of value may be gathered during the collecting, and should be put into convenient form so that it may be readily consulted. The collection prepared by Señor Gamba originally fulfilled to a high degree the conditions of an ideal collection. Unfortunately, the account of the mining and geology of Colombia, which was written to accompany it, was entrusted to careless hands and lost, and only a portion of the collection itself reached the Museum. The collection now in the Museum consists of 116 specimens from the original 425, and they are accompanied by a manuscript catalogue of the original collection. It has been the purpose of my study to determine accurately the minerals and rocks of this collection and the nature of the deposits, so far as this is possible, from an examination of the specimens. For this purpose every specimen in the collection has been carefully examined, all doubtful minerals have been tested, and slides of all rocks have been made and studied. Of course, the names of the rocks, as thus determined, differ from the local names given in the catalogue. Many rocks, the specimens of which were not available for study, have been determined by the aid of the fragments of rock which cling to the ore specimens. In the catalogue following, the specimens have been listed under their respective mining districts. Besides such data upon the nature of the deposits as could be gathered from the catalogue and from a study of the specimens, there has been prefixed to the list from each district such brief account of the location, character and importance of the district as could be gathered. The data for these accounts was obtained for the most part from the works of Vicente Restrepo and Elisée Reclus. The specimens which are in the collections of the Field Columbian Museum are given the Museum catalogue number in the lists on the following pages, and may, by this means, be distinguished from those specimens which are missing from the present collection. The results of study of these specimens have been incorporated in the catalogue. As this is a collection from those mines only which were in operation in 1892, it obviously does not include specimens from all the old mines worked when Colombia was at the height of her importance as a gold producer. Also, it cannot contain specimens from any mines which may have been opened during the last seven years. Nor does it bear upon the potential resources of the country in the form of undeveloped deposits, which is, on the whole, advantageous, for it confines the collection to specimens from deposits of known value. The secondary deposits, *i. e.*, the placers, of Colombia are not represented in this collection. This, indeed, is not customary, for very little may be learned from such a collection of gravels. Within these limitations, the collection was, in its original form, practically complete. It is not improbable, however, in a country where travel is as difficult as it is in Colombia, that a few isolated mines were overlooked, as might be done without imparing, in any material way, the value of the collection. One such mine with a twelve-stamp mill was noticed by Dr. G. A. Dorsey, of the Museum, at Ensolvado, in the Upper Cauca valley, near Popayan

PHYSICAL FEATURES AND GENERAL GEOLOGY.

Physically, Colombia may be divided into two regions, the Eastern Plains or Llanos of the Orinoco, and the Western mountains. The Andes, entering Colombia from the south, divide into three approximately parallel chains, the Eastern, Central and Western Cordilleras. These are sometimes known as the *Sierra del Choco*, *Sierra del Quindiu* and the *Sierra del Suma Paz*, respectively. They are separated by the deep, longitudinal valleys of the Cauca and the Magdalena, the important waterways of the republic. It is in these three chains that the ores occur. The Western and Central Cordilleras are much richer than the Eastern. Besides these three ranges there is in the North the great *massif* of Santa Marta, which Reclus considered to be not a part of the Andean system. On the North and West a chain of the Andes enters the Isthmus of Darien from Central America and dies out in hills on the northwest coast. In this region it is separated from the *Cordillera Occidentale* (the Western Cordillera) by the Atrato Valley. In this chain there were formerly many mines, one of which, the Espiritu Santo, has been reopened recently. In the past, mines were worked in many parts of the country as placers are at present. In 1892, when this collection was made, mines in operation existed with but few exceptions only in the two mountain Departments of Antioquia and Tolima. The great valleys of the Atrato, the Cauca, and the Magdalena, are very deep, so that strips of tropical climate extend much farther into the mountains than the map suggests. Even in the mountainous state of Antioquia, mining districts have been deserted on account of the hot, dangerous climate. On the other hand, the peaks and ridges are placed upon broad bases, so that, excluding the Llanos, a very considerable portion has a temperate climate. It is in these temperate zones that mining is now carried on. For a full account of the physical geography and climatology of Colombia the reader may consult "The Earth and its Inhabitants—S. America," vol. 1, by Elisée Reclus.

According to Dana the highest peaks of the Eastern Cordillera are Upper Cretaceous. Prestwich, following David Forbes and M. Pissis, states that in the Andean regions the Quaternary of the coast is succeeded by Oölitic ranges, which, in turn, overlie Permian and Triassic strata, while the central regions are of Devonian and Silurian age. The mountains, he says, were raised in four upheavals, of which the first occurred in the Permian or Triassic. John C. Randolph (see p. 159) finds, in the Magdalena valley, Archæan schists, on which lie Triassic sandstones and Jurassic limestones. The author of the article on Colombia in the Encyclopedia Britannica,* says: "The fundamental formations of Colombia are igneous and metamorphic, the great masses of the Cordilleras consisting of gneiss, granite, porphyry and basalt. In many places the Carboniferous strata have attained considerable development, though they have been thrown into strange confusion by some unknown disturbance." With the Museum collection there is a specimen of encrinal limestone from the Department of Santander which appears to be of Subcarboniferous age, although none of the fossils are in such condition that they can be determined positively. There is also a very fair specimen of bituminous coal from Titiribí, in Antioquia, and coal is reported from many localities. The sedimentary rocks in the Departments under consideration, Antioquia and Tolima, are everywhere mingled with and penetrated by eruptives, said to be largely andesites. According to Robert White,† the Eastern Cordillera is almost all volcanic, while the rest of the Cordilleras are composed of granites, granitoid rocks and diorites. From specimens in the collection it would appear that dacites, trachytes and rhyolites are not uncommon. The earlier of these lavas were erupted during the great disturbance closing the Tertiary. There has been much volcanic activity in the region ever since. At the present time there are a number of active and dormant volcanoes there. For a fuller account of the geology, see the article by Randolph referred to above, and also "The Manganese Deposits of the Department of Panama, Republic of Colombia." ‡

---

*As quoted in the Handbook of Colombia, p. 9.

†Rep. Br. Assn. Adv. Sci., 1882, p. 552.

‡Eduardo J. Chibas. Tr. A. I. M. E.. vol. xxvii., 1897. p. 63.

THE MINING DISTRICTS AND ORES OF ANTIOQUIA.

The Department of Antioquia, situated in the heart of the Andes, between the Western Cordillera and the Magdalena River, is everywhere traversed by quartz veins, which vary from 8 inches to 6½ feet in width. These veins are of two classes: the *vetas de cajon*, which vary in inclination from vertical to forty-five degrees, and the *vetas de sombre*, which are more nearly horizontal. These veins are all auriferous and grow poorer in depth.* A third class of deposits is indicated by the specimens in this collection, and will be described with the Southern deposits. According to Mr. Nye F. Morton, an American prospector, who spent many years in the region, these veins are numerous and persistent over long distances. They are everywhere auriferous, but generally of too low grade to work. Rich pockets are of frequent occurrence, but they are small and irregular in distribution. Workable portions are few and far between. Among the specimens of the Gamba collection there is an abundance of fresh, undecomposed sulphide ores, which indicate deep mines, as, owing to the climate, the surface alteration has penetrated to some depth. Besides pyrite and blende; arsenopyrite, galena and chalcopyrite occur in small quantities; also, rarely, stibnite, chalcocite, and ruby silver. Molybdenite, wulfenite, argentite and tetrahedrite have been found with the ores. The gangue is usually quartz, which is associated with dolomite and limestone in the silver districts.

According to Restrepo, the deposits are found in granite, syenite, diorite, syenite- and feldspar-porphyries, mica, talc and clay schists, limestones and dolomites. Gamba's catalogue gives the following varieties of country rock: Granite, gneiss, syenite, diorite, andesite, trachyte, diorite- and syenite-porphyries, phonolite, porphyrite, limestone, conglomerate, sandstone, slate, quartzite and schist, including hornblende and "*negro-negro*" schists. Robert White† mentions granite, syenitic granite, diorite and porphyry. These lists are, however, very misleading, for the names given are applied according to local significations, very different from the meanings they usually carry. From a comparison of the specimens in the collection with the names in the catalogue, it appears that the rocks mentioned above really include but a few species. Gneiss, diorite, mica schist and limestone are found in a few mines. All the other rocks mentioned are really andesites, dacites, trachytes, rhyolites and their tuffs, with small quantities of some basic lava, possibly a basalt.

---

*Restrepo. Gold and Silver Mines of Colombia, p. 7.

†Min. Res., iv., p. 635.

Antioquia produces much gold and little silver. The gold follows the pyrite and the silver the blende. The ores become more argentiferous southward, and the content in zinc increases at the same time. The only true silver mines are in the Titiribí district in the south.

The deposits may be separated into three groups: The North Central, the Western, and the Southern deposits.

THE NORTH CENTRAL DEPOSITS. These are the deposits of the Nechi and Porce valleys and the Central Cordillera. The specimens indicate that the deposits are quartz veins of the familiar type. This is confirmed by Whitney.* In the unoxidized ores the sulphide is pyrite, with which are mingled very small quantities of galena and blende. In some districts arsenopyrite replaces the pyrite. The North Central deposits include the districts of Remedios, Amalfi, Santa Rosa de Osos, Anori and San Pedro.

THE WESTERN DEPOSITS. These are upon the west side of the Western Cordillera and upon the slopes of the Atrato Valley. The nature of these deposits I could not definitely ascertain, but they appear to be quartz veins of the ordinary type. Although these veins are auriferous, there is considerable calcite in the gangue, and in one of the districts there is the unusual case of an important gold deposit in limestone. The ores in the unoxidized portions are pyrite and arsenopyrite, associated with more blende and galena than is the case in the North Central districts. Chalcopyrite is also present, and in places the ores assume a distinctly coppery character. Tellurides of gold are also found in the mines of this region. The western deposits include those of Anza and Frontino.

THE SOUTHERN DEPOSITS. These are very different in character from those already mentioned. The ores are chiefly blende, mingled with pyrite and galena. Antimony replaces the arsenic of the more northern districts. The specimens indicate that the deposits are, in part, auriferous silver ores in quartz, and, in part, argentiferous gold ores in calcite and magnesite. The quartzose ores appear to be metasomatic deposits in a brecciated zone of acid lavas, while the calcareous deposits are segregation veins in acid tuffs. A discussion of the features of these deposits will be found in the accounts of the various districts. The southern deposits include those around Titiribí, Supía, Caramantá and Manizales, some of which are across the boundary in the adjoining Department of Cauca. The mines of Antioquia are wholly gold mines, except for a few mines in the southern part, which partake of the characters of the deposits of Tolima.

---

*Mineral Wealth of the United States, p. 109.

GOLD MINING DISTRICT OF REMEDIOS.

Remedios, lat. 7° 10′ N., long. 74° 55′ W., is situated in the North Central part of Antioquia, a few miles south of the re-entrant angle made by the boundary of the Department of Bolivar. It was founded in 1560 on the Ite river, a branch of the Magdalena, for the sake of the rich placers there. On account of the deadly climate it suffered several removals, but finally occupied the site of Las Quebradas, where it now is. For many years after its foundation the chief industry was placer mining. About 1840 the quartz veins began to be exploited, and now they much exceed the placers in importance. In 1886 the veins were said to produce over 300 pounds of gold per month. As this gold ranges in fineness from 579 to 638, this corresponds to a value of over $43,000 per month. The ores are typical quartz-pyrite vein material. The quartz in the unoxidized specimens is hard and firm, and greatly exceeds in quantity the sulphide, which occurs as parallel bands of coarsely crystalline pyrite, with very small quantities of galena and blende. Other sulphides appear to be absent. A specimen from the Silencio mine indicates a seven-inch vein. The mines are represented in the collection by a much larger number of sulphide than of oxidized specimens, and the sulphides are clean and fresh, indicating that the mines, even with the necessary slowness of working, have reached a considerable depth. The surface ores are rusty brown quartz, locally called "*colorado*," from a Spanish word, originally meaning colored, but later coming to mean red or brown. In some specimens the gold is visible as coarse scales. These ores occur in quartz veins, which are horizontal or of slight inclination (*vetas de sombre*). The country rock of one mine, the Santa Isabel, is a dark, fine-grained, very basic hornblende gneiss. That of the others is a rock locally called syenite, but really an andesite or trachyte. A formation described as a limestone dike (!) is probably a vein of calcite. An intrusive of "hornblendic" (chloritic) material is described in the catalogue as occurring in the Cordova mine, and a porphyritic rock occurs in like manner in the Providencia mine.

From this district Señor Gamba collected 61 specimens, representing twelve mines. The series is as follows:

"1. Syenite, the wall rock of all veins of the district."

The term "syenite" seems to be locally applied to any gray, granular, quartz-free rock. In this instance, judging from fragments enclosed in specimen No. 15 and others, the rock is an andesite or a trachyte. The specimens examined were too much altered by the action of the vein liquors for exact determination.

Syenites and granites are constantly referred to, not only in this catalogue, but in all works on the subject. Whenever it has been possible to examine the specimens, the author has invariably found them to be andesites or similar rocks. It may be noted here that Chibas,* quoting Karsten, says: "During the upheaval, volcanic forces seem to have been very active in some portions of the country and eruptions of porphyry, granite and syenite took place." This would seem to indicate that volcanic rocks were referred to under these names.

"2. Hornblendic material, intrusive in syenite in the Cecilia vein."

Here and generally in this catalogue, the expression, "hornblendic material," or "hornblendic rock," is to be interpreted as referring to an eruptive rock which has become very chloritic through alteration. This specimen doubtless corresponds to the chlorite schist of No. 133.

"3. Ore from the Cecilia vein."

"4. Veinstuff from the Cecilia vein."

"5. Decomposed ore from the Victoria mine."

"6. Decomposed ore from the Victoria mine."

"7. Clay from the vein, Victoria mine."

"8. Hornblendic material, intrusive in Cordova mine." (See No. 2.)

"9. [E 1650.] Quartz, ore from the Cordova mine."

This is a clean, milky quartz, with slight iron stains. A few scattered galena crystals are present, but no pyrite.

"10. Quartz, ore from the Cordova mine."

"11. Quartz, ore from the Cordova mine."

"12. Quartz, ore from the Cordova mine."

"13. Quartz and pyrites, ore from the Cordova mine."

---

*Loc. cit.

"14. [E 1047.] Quartz and pyrites, ore from the Cordova mine."

This is a white, milky quartz, with stained seams. It contains about 25 per cent. of pyrite in large cubes.

"15. [E 1048.] Quartz and pyrite, ore from the Cordova mine."

This is a white, milky quartz, with iron-stained seams weathered in about an inch. About 10 per cent. pyrites and galena in about equal quantities partially fill cavities which extend through the specimen in the form of parallel bands. Some open seams are lined with crystals, and there are inclusions of a granular kaolinized material, which is apparently a decomposed acidic country rock. The pyrite, in the form of pyritohedrons, was deposited in part simultaneously with the galena and in part later. This is shown by crystals composed of galena, which enclose pyrite in irregular forms, and are partially enclosed, in turn, by pyrite. There are also pyrite crystals on galena.

"16. Quartz and pyrite, ore from the Silencio mine."

"17. [E 1049.] Quartz and pyrite, ore from the Silencio mine."

This is crystallized and milky quartz, with about 5 per cent. of pyrite in detached crystals. There is a comb structure of quartz crystals through the center, and the pyrite forms a band on either side. A little blende sometimes occurs enclosed in pyrite crystals. It contains enclosures of andesite or rhyolite, similar to those of specimen No. 15.

"18. Quartz and pyrites, ore from the Silencio mine."

"19. Quartz and pyrites, ore from the Silencio mine."

"20. Quartz and pyrites, ore from the Silencio mine."

"21. [E 1649.] Pyrites, ore from the Silencio mine."

"22. Concentrates from the ore, Silencio mine."

"23. Pyrites, ore from the Silencio mine."

"24. Quartz, ore from the Silencio mine."

"25. Quartz, ore from the Silencio mine."

"26. Quartz, ore from the Silencio mine."

The mines listed above were worked at the time the collection was made, by an English company, the Frontino & Bolivia Mining Co. Most or all of these mines are on what was formerly known as the Bolivia vein.

"27. Ordinary quartzose ore from the Cristales mine."

"28. Crystallized quartz from the Cristales mine."

"29. Quartz, ore from the Cristales mine."

"30. Pyrites, ore from the Cristales mine."

"31. Limestone dike (*sic*) in the syenitic formation of Remedios."

The interesting specimen thus catalogued is unfortunately missing from the collections. It is uncertain whether this is merely bad English for a calcite vein, or whether it refers to a porphyrite or other dike, the material of which is so kaolinized as to resemble limestone.

"32. Quartz and pyrites, ore from the Cogotes mine."

"33. *Colorado* ore with native gold from the Cogotes mine."

A *colorado* ore is an oxidized ore, which takes its name from the red-brown iron stains which often accompany such ores.

"34. Quartz and pyrites, ore from the Cogotes mine."

"35. Quartz, ore from the Cogotes mine."

"36. *Colorado* ore from the Italia mine."

"37. [E 1050.] *Colorado* ore from the Italia mine."

This is a good example of the "*colorado*" or iron-stained ore. It is a firm quartz of a pinkish cast, strongly iron-stained along the seams, and honeycombed in places where pyrite has been dissolved out. It contains many angular fragments of kaolinized country rock, similar to that of the other specimens. The small pseudomorphs of hematite after pyrite and blende, which usually occur in such ores, are present.

"38. Veinstuff from the Pujidos mine."

"39. Quartz, ore from the Pujidos mine."

"30. Pyrites, ore from the Pujidos mine."

"41. Quartz and pyrites, ore from the Pujidos mine."

"42. Ore from the Providencia mine."

"43. Ore from the Providencia mine."

"44. Ore from the Providencia mine."

"45. Quartz, ore from the Providencia mine."

"46. Quartz and pyrites, ore from the Providencia mine."

"47. Porphyritic rock, intrusion in the Providencia mine."

"48. [E 1051.] Quartz, ore from the Providencia mine."

This resembles specimen No. 15, except that the galena is in very small quantity.

"49. Ore from the Providencia mine."

"50. [E 1052.] Ore from the Providencia mine."

This clear, white quartz, which is somewhat iron-stained on the seams, contains a few small undecomposed pyrite crystals and a few casts of larger ones, either filled with limonite pseudomorphs, or containing quartz crystals.

"51. Ore from the Providencia mine."

"52. [E 1053.] Ore from the Sucre mine."

This is an iron-stained quartz, thoroughly impregnated with fine-grained, light-colored, iron pyrites.

"53. Quartz, ore from the Sucre mine."

This is a *colorado* ore of white quartz, iron-stained in the seams, with inclusions of limonite and of a clay-like mineral.

"54. Quartz, ore from the Sucre mine."

"55. Pyrites, ore from the Sucre mine."

"56. Quartz, ore from the Sucre mine."

"57. Colorado ore with native gold from the Providencia mine."

"58. Ore from the Estancon mine, near Santa Isabel."

"59. [E 1055.] Ore from the Estancon mine, near Santa Isabel."

This is a much-seamed white quartz, with some seams slightly iron-stained. The sulphides are in the form of a band, containing pyrite and galena, accompanied by cavities which contain a few pseudomorphs of limonite. There is perhaps twice as much galena present as pyrite, the latter appearing to be of later origin.

"60. Gneiss from the wall rock in the Santa Isabel mine."

"61. [E 1056.] Quartz, ore from the Santa Isabel mine."

"62. Quartz, ore from the Santa Isabel mine."

"63. [E 1057.] Pyrite, ore from the Santa Isabel mine."

This white quartz, with stains of limonite, shows a redeposition of pyrites in the cubical cavities now containing limonite, from which an older generation of pyrite had previously been dissolved. A cellular pyrite partially fills cavities in the quartz, apparently left by a previously dissolved pyrite of much coarser crystallization.

"64. [E 1058.] *Colorado* ore with native gold from the Santa Isabel mine."

This is an impure yellow-stained quartz, much brecciated, with some kaolinized country rock attached. The quartz is schistose from shearing. Between some of the sheets are cellular planes filled with quartz crystals and loose limonite. Wire gold is found scattered in numerous irregular clusters over these crystals.

"65. [E 1059.] *Colorado* ore with native gold from the Santa Isabel mine."

This iron-stained brecciated quartz contains irregular cavities. Little free gold is visible.

GOLD MINING DISTRICT OF AMALFI.

Amalfi lies on the east bank of the Porce River, southwest of Remedios, on the road to Santa Rosa. It was founded in 1840, and, owing to its favorable situation, soon became a more important place than the older towns of Remedios and Zaragosa. Its population in 1880, according to Reclus, was 6,600. It lies at an elevation exceeding 4,750 feet, and consequently is free from the tropical heat and consequent fever of the low-lying towns of the north. Mining of the veins began at about the same time as at Remedios. The deposits resemble those of Remedios, being quartz veins in pyroxene dacite, locally called granite, with intrusives of chloritic altered andesite or trachyte, locally called "hornblende," and of a porphyritic rock. The veins are *vetas de cajon*, or veins steeply inclined to the horizon; and, therefore, differ from those of Remedios in some respects.

Like those of Remedios, the ores are of the quartz-sulphide type. The pyrite of the Remedios deposits is here replaced largely by arsenopyrite, and the ores are in consequence very arsenical.

From this district Señor Gamba collected 22 specimens, representing 12 mines. The series is as follows:

"66. Granite from Amalfi."

This specimen of the "granite of the later period" (*Humboldt*) is unfortunately not in the collection, and consequently could not be verified.

The dacite of specimen No. 76, from a mine of this district, is a rock which cannot be distinguished from a granite by meagscopic examination, and as no specimens of true granites are found in the collection, this will be considered as a pyroxene dacite until a specimen of it becomes available for examination.

"67. Wall rock from the Chuchero mine."

"68. Quartz, pyrite and arsenopyrite, ore from the Chuchero mine."

"69. Quartz and arsenopyrite, ore from the Chuchero mine."

"70. Quartz, ore from the Chuchero mine."

"71. Quartz, ore from the Chuchero mine."

"72. Quartz, pyrite and arsenopyrite, ore from the Chuchero mine."

"73. Quartz, pyrite and arsenopyrite, ore from the Chuchero mine."

"74. Decomposed ore from the Lola mine."

"75. Decomposed ore from the Lola mine."

"76. [E 1060.] Wall rock from the Clara mine."

This is a gray, coarsely crystalline and very quartzose pyroxene dacite. It is unaltered, except for the feldspars, which are so much kaolinized that the varieties cannot be determined. The phenocrysts of quartz, pyroxene and plagioclase are very much corroded, and retain little of their original outlines. The ground mass consists of an indeterminate mixture of rather large lath-shaped crystallites. The quartz is very abundant.

"77. Quartz, ore from the Clara mine."

"78. [E 1061.] Quartz and arsenopyrite, ore from the Clara mine."

Firm, unweathered granular quartz, with a streak of coarse arsenopyrite crystals along the center.

"79. Quartz and arsenopyrite, ore from the Clara mine."

"80. Granite from the Clara mine."

This specimen is not in the Museum collection, and consequently could not be examined. The remarks under specimen No. 66 will apply here, and the specimen is doubtless a pyroxene dacite.

"81. Decomposed granite from the Clara mine."

This specimen also is not in the present collection. The specimen is doubtless an altered form of specimen No. 80, and is here considered to be an altered dacite.

"82. Hornblendic rock, false wall in the Clara mine."

Like the two preceding, this specimen is not in the Museum collections. From analogy with a number of rocks, given the same or similar names in the catalogue, there is little doubt but this is a specimen similar to No. 133, that is, a chlorite schist, resulting from the alteration of andesite or trachyte.

"83. Quartz, ore from the Clavellina mine."

"84. Quartz, ore from the Clavellina mine."

"85. Quartz and arsenopyrite, ore from the Clavellina mine."

"86. Quartz, ore from the Chuchero mine."

"87. Ore from the Santa Catalina mine."

GOLD MINING DISTRICT OF ANORI.

Anori, at an elevation of over 4,700 feet, saw the beginning of vein mining in Colombia. About 1852 the first veins were worked, and crushing machinery put in. The country rock is mica schist, according to Restrepo, and the deposits are of the class *vetas de cajon.* The ores, like those of Amalfi, are arsenopyrite in quartz. The only specimen from this town collected by Señor Gamba (88, E 1062), is a specimen of firm, unweathered quartz, with a few small crystals of arsenopyrite. It comes from the Constancia, one of the two oldest and most productive veins there. Between Amalfi and Santa Rosa de Osos, Señor Gamba collected the following specimens:

"89. Porphyry from dikes in the road between Amalfi and Santa Rosa."

"90. Porphyry from dikes in the road between Amalfi and Santa Rosa."

"91. Porphyry from dikes in the road between Amalfi and Santa Rosa."

"92. Syenite from the Porce River on the road between Amalfi and Santa Rosa."

The remarks under specimen No. 1 will apply to this "syenite" as well. It is here considered to be one of the acid lavas.

GOLD MINING DISTRICT OF SANTA ROSA DE OSOS.

Santa Rosa de Osos y Remedios lies in the Porce Valley, southwest of Amalfi. It is situated at an elevation exceeding 4,700 feet, and has a mean annual temperature of only 58°. In 1880 its population was 10,000. It probably ranks third in importance of the mining districts of Antioquia, coming after Remedios and Titiribí. Ores are found in the so-called syenite, mica schist, and gneiss, according to Gamba. As before, syenite is to be interpreted as trachyte and andesite. Phonolite is mentioned from one mine. The deposits consist of quartz *vetas de cajon.* All deposits along the Porce Valley are said by Whitney,* to be quartz veins of the ordinary type. From this district Señor Gamba collected twenty specimens, representing four mines. The series is as follows:

"93. Mica schist from Santa Rosa de Osos."
"94. *Colorado* ore from the Trinidad mine."
"95. *Colorado* ore from the Trinidad mine."
"96. *Colorado* ore from the Trinidad mine."
"97. *Colorado* ore from the Trinidad mine."
"98. Undecomposed quartz from the Trinidad mine."
"99. Undecomposed quartz from the Trinidad mine."
"100. Syenite."

---

* "Metallic Wealth of the United States," p. 109.

As in previous instances, read andesite or trachyte for syenite. This specimen is not in the collections.

"101. Phonolite from the San Miguel mine."

"102. Quartz ore from Juan Sanchez mine."

"103. [E 1063.] Decomposed ore from the San Miguel mine."

A very yellow brecciated quartz with ochreous limonite.

"104. Decomposed ore from the San Miguel mine."

"105. Decomposed ore from the San Miguel mine."

"106. Decomposed ore from the San Miguel mine."

"107. Pyrite, ore from the San Antonio mine."

"108. Pyrite, ore from the San Antonio mine."

"109. *Colorado* ore from the San Antonio mine."

"110. [E 1064.] *Colorado* ore from the San Antonio mine."

This is a rusty quartz with pyrite.

The pyrite, while retaining its crystalline form, is filled with straight cracks, for the most part microscopic, which follow octahedral planes, and are filled with quartz.

"111. *Colorado* ore from the San Antonio mine."

"112. [E 1065.] Gneiss from near Santa Rosa de Osos."

This is a black, very schistose rock. Under the microscope it appears as a rock, composed principally of hornblende, with some quartz, and bands of a feldspar, which appears as a microperthitic intergrowth of albite and orthoclase. There are also a few crystals of microcline, and of a feldspar which shows the plagioclase twinning.

GOLD MINING DISTRICT OF SAN PEDRO.

About twenty-five miles south of Santa Rosa is Medellin, the capital of Antioquia. It is a place of 30,000 inhabitants, on the bank of the Medellin River, a branch of the Porce, and at the foot of the Santa Elena Mountain, a peak of the range upon the flanks of which Santa Rosa lies. From San Pedro, a village near Medellin, Señor Gamba collected three specimens of gold ores. These ores are not in the Museum collections, and there is no information available concerning this district.

GOLD MINING DISTRICTS OF WEST ANTIOQUIA.

The districts already mentioned are upon the Central Cordillera, along the Cauca Valley. The districts of Frontino and Anzá are upon the Western Cordillera. In the North-Central Districts of Antioquia the ores are associated with lead and zinc minerals. The sulphides are pyrite and arsenopyrite, associated with blende and galena, with but little chalcopyrite. In these western districts the ores assume a coppery character, and native copper has been reported from Frontino. The sulphides from Frontino in the Museum collections would be considered in this country as auriferous copper ores. Pyrrhotite and chalcopyrite replace the pyrite and arsenopyrite. Auriferous tellurides are present, and in the oxidized specimens cubo-octahedrons of free gold are common. The ores occur in quartz veins. With the quartz in the specimens from both Frontino and Quiuná, there is more or less calcite. The gold from Frontino is given by Restrepo as 781 fine, while that of Quiuná is 919 fine. The two mines worked in the district are very old. The sale of the Frontino mine to an English company is mentioned as taking place in 1852, and the Quiuná mine was discovered by Antonio Salzaar in the latter part of the eighteenth century. Frontino is situated at the head waters of the Rio Sucio, the largest affluent of the Atrato, which is reputed to be one of the richest and unhealthiest streams in the world.

The country rock at Frontino is a coarsely crystalline diorite. The specimen studied came from near the vein, and was much altered; serpentinization of the hornblende was far advanced. None of the feldspar could be determined. There was very little kaolinization, and a large amount of calcite was present. The ores are found in a quartz vein, which, according to Whitney (1854), varied from two inches to five feet in thickness.

From the Frontino mines Señor Gamba collected the following fifteen specimens:

"117. Diorite from the Frontino mine, Frontino." (See No. 125.)

"118. Diorite from the Frontino mine, Frontino." (See No. 125.)

"119. [E 1066.] Quartz and chalcopyrite."

This is a specimen of vein quartz, with chalcopyrite and pyrite. It was apparently fresh and unaltered when taken from the ground. The pyrrhotite is very magnetic, and is as liable to decomposition as is marcasite. Since it has been in the Museum it has decomposed to a great extent, covering the specimen with white crystals of epsomite, and with an indeterminate mixture of oxides and sulphates. The operation has broken up a good part of the ore into a breccia, which, if recemented at any time, would have the appearance of a typical brecciated vein.

"120. Corundon [*Corundum?*] from the Frontino mine."

"121. Corundon [*Corundum?*] from the Frontino mine."

"122. Copper ores from the Frontino mine."

"124. Quartz and pyrite, ore from the Frontino mine."

"125. [E 1067.] Ore with telluride of gold from the Frontino mine."

One face of this specimen is a thin seam of quartz, containing numerous crystals of gold. Those projecting far enough from the matrix for determination are cubes modified by the octahedron. With the gold are a few scattered grains of telluride, in quantity too small for an exact determination of the species. The country rock attached to this specimen looks like a rather coarse-grained, light-colored diorite. Under the microscope it appears as a much decomposed, coarsely crystallized diorite, impregnated with calcite.

"126. Ores with telluride of gold from the Frontino mine."

"127. Ores with telluride of gold from the Frontino mine."

"128. Ores with telluride of gold from the Frontino mine."

"129. Ores with telluride of gold from the Frontino mine."

"130. Felsitic rock from the Frontino mine."

"131. [E 1648.] Pyritic ore from the Frontino mine."

This is chalcopyrite mixed with massive, very magnetic pyrrhotite, with crystals of calcite in quartz. The pyrrhotite in this specimen like that in No. 119 is rapidly decomposing.

"132. Pyritic ore from the Frontino mine."

Anzá is upon the eastern slope of the Western Cordillera, on the flanks of the Cauca Valley, about eighteen miles south of the city of Antioquia, the ancient capital of that department.

The unusual case of a gold mine in limestone is presented by the Quiuná mine. This is a mine on an auriferous quartz vein in limestone. With the vein there occurs a chlorite schist, similar in character to the metamorphic andesites common in the Mexican mining regions.

From Anzá, Señor Gamba collected eight specimens, representing one mine:

"133. [E 1067.] Hornblendic rock from the Quiuná mine."

A green chlorite schist, of the usual kind, *i. e.*, a metamorphosed andesite.

"134. Hornblendic rock from the Quiuná mine."

This specimen, which is not in the collection, was probably another chlorite schist.

"135. Limestone from the Quiuná mine."

"136. Limestone from the Quiuná mine."

Besides the limestone country rock of the Quiuná mine, calcite occurs among the gangue minerals of the Frontino mine, and is the major part of the gangue mineral proper in the famous Espiritu Santo mine, on the Isthmus of Darien, where the ore occurs with calcite in small pockets (*amygdules?*) in one of the more acidic lavas.*

"137. Quartz from the Quiuná mine."

"138. Quartz and limestone from the Quiuná mine."

"139. Quartz and limestone from the Quiuná mine."

"140. Quartz and limestone from the Quiuná mine."

IRON MINING DISTRICT OF AMAGÁ.

Amagá, a town of 6,400 inhabitants, upon the Central Cordillera, situated on the east side of the Cauca Valley, about twenty miles southwest of Medellin, is the seat of the Colombian iron mining and smelting industry. Formerly gold mines were worked there, but none are listed by Señor Gamba as being in operation at the present time. According to his catalogue, the country rock of the region is sandstone, associated with porphyry.

A number of deposits of coal are given in Reclus' map of the region. The iron ores, judging from the Museum specimens, are light brownish-yellow, shaly siderites. They are smelted at Amagá.

From Amagá Señor Gamba collected the following eight specimens:

"141. Sandstone."

"142. Porphyry."

"143. [E 1196.] Iron stone."

An impure shaly siderite.

"144. Iron stone.'"

"145. Iron stone."

"146. White iron from the Amagá furnaces."

"147. Gray irons from the Amagá furnaces."

"148. Quartzite from the road between Amagá and Zancudo."

---

*"The Darien Gold Mining Region of Colombia": E. J. Chibas, Eng. Mag., Vol. XVI., p. 49. 1898.

SILVER MINING DISTRICT OF TITIRIBÍ.

The content of the Antioquian ores in silver increases southward, until at Titiribí the mines opened for gold are now operated for silver.

Titiribí (*Sitio Viejo*) and Sabalétas, two mining towns near Amagá, compose the Titiribí district. The population of Titiribí in 1880 is given as 9,200, a figure which probably includes the population of Sabalétas. The deposits are grouped by Restrepo with those of Remedios as *vetas de sombre*, or horizontal veins; but while the specimens from Remedios have all the characters of fissure vein material, those from the largest group of mines (the Zancudo Establishment) in Titiribí, appear to be impregnations of a brecciated zone in the trachyte. The country rock of the Zancudo mines is given by Gamba in his catalogue as porphyrite, trachyte and hornblende schist. No specimens of these rocks are now in the collection, but portions of the wall rock remain attached to many of the specimens. These consist of a light-buff colored compact rock, with a well developed flow structure. As might be expected from specimens coming only a few inches from the ores, they are too much altered for determination. Under the microscope they appear as confused aggregates of exceedingly minute crystals of secondary minerals, penetrated in every direction by microscopic veinlets of quartz. A well defined flow structure is all that remains of the original features of the rock beyond a faint impression here and there of a portion of the outline of phenocrysts which have altered so as to be indistinguishable from the ground mass. While this may be an altered form of either the porphyrite or the trachyte, from its large development in the Zancudo mine it will be considered here as an altered trachyte. One specimen contains a fragment of the hornblende schist, which proves to be similar in character to the rock common among the Mexican mines. It is there known as chlorite schist, and is generally regarded as a metamorphosed andesite. The ores consist of a mixture of blende, which is the most abundant sulphide, and pyrite, with small quantities of galena, pyrrhotite and chalcopyrite, all cemented by quartz. The sulphides form a very large proportion of the vein material. This material occurs as an impregnation and replacement, partial or complete, of a brecciated zone in the trachyte. All stages of the replacement are plainly shown in the specimens. The first stage is a breccia, which is cemented by a finely granular mixture of sulphides and quartz, while at the same time minute pyrite crystals appear in the fragments of trachyte. From this stage the replacement proceeds in two ways, which often appear in the same specimen. The less common way is for the replacement to take place from without inward. The rock disappears on the outside of the fragments, and is replaced by a granular aggregate of sulphides in quartz which form a band around the trachyte within. The more common way, however, is for the alteration to take place throughout the body of the fragment. The number and width of quartz veinlets shooting across the trachyte increases as well as the amount of pyrite and other sulphides occurring as separate crystals, until the rock has been entirely replaced, and all that can be seen of the original fragments is an indistinct angular outline, which also disappears in time. In the specimens from the Zancudo mines the following accessory minerals were noticed: Cobweb-like forms of jamesonite, incrusting forms of aragonite, crystals of siderite and dolomite and arsenopyrite in needles.

ZANCUDO ESTABLISHMENT.

Though only four mines appear by name in the catalogue, in reality there are more than that number represented, since a number of them have long been consolidated under one management as the Zancudo Establishment. According to a report by Señor Don I. Guitterez, the Zancudo Establishment included in 1884 the Zancudo mine with a smelter at Sabalétas, a smelter and mines at Titiribí (*Sitio Viejo*), the Chorros and other mines. The Establishment owned, in 1884, 202 stamps, and a proportionate number of concentrating appliances, blast and reverberatory furnaces, cupels, etc. The bullion produced was silver, with about seven per cent. gold.

The following specimens were collected by Señor Gamba at the Zancudo mine:

"149. Porphyry from Sabalétas."
"150. Porphyry from the Zancudo mine."

The specimens noticed were without phenocrysts, and had better be termed felsite.

"149. Porphyrite from Sabalétas."
"150. Porphyrite from the Zancudo mine."
"151. Trachyte from the Zancudo mine."
"152. Hornblende schist, wall rock of the Zancudo mine."
"153. Mineralized schist from the Zancudo mine."
"154. [E 1068.] Ordinary ore from the Zancudo mine, called *molino* (milling ore)."

This specimen is not of vein material. It is a contact between a chloritic schist (like No. 133) and an altered trachyte heavily impregnated with pyrite, chalcopyrite, galena and blende, with some strongly magnetic pyrrhotite. Aragonite occurs in minute incrustations.

"155. [E 1197.] Ordinary quartzose ore from the Zancudo mine."

Dark-colored quartz impregnated with sulphides, like those of No. 154, and with many angular fragments of the light-colored altered trachyte, which are penetrated everywhere by numerous small quartz veins. The formation does not appear to be that of a brecciated vein, but rather to have originated by metasomatosis of the trachyte.

"156. Ordinary quartzose ore from the Zancudo mine."

"157. [E 1069.] Pyrites and blende, *scheiderz* from the Zancudo mine."

Scheiderz is defined as an ore which has been separated from the poor ore and gangue by picking over by hand.

In this specimen, pyrite, blende and galena coat and impregnate colorless granular quartz.

"158. *Molino* ore from the Rosario mine."

"159. [E 1070.] *Molino* ore from the Rosario mine."

Here blende, pyrite, galena and quartz replace a trachyte breccia. The specimen contains some unaltered trachyte and some compact quartz and sulphide in which the breccia is not visible.

"160. *Molino* ore from the Rosario level, Zancudo mine."

"161. Veinstuff, feldspathic clay from the wall rock of the vein."

"162. [E 1207.] Pyrite and blende, *scheiderz* from the Zancudo mine."

"163. *Scheiderz* with galena."

"164. Ordinary quartzose ore from the Rosario level, Zancudo mine."

"165. Galena, ore from the Zancudo mine."

"166. Ordinary quartzose ore from the Paz level, Zancudo mine."

"167. Ordinary quartzose ore from the Paz level, Zancudo mine."

"168. Quartzose *molino* ore from the Paz level, Zancudo mine."

"[E 1071.] Quartzose *scheiderz* from the Paz level, Zancudo mine."

This is a mixture of chalcopyrite, blende and galena which thoroughly impregnates a light, granular quartz.

"170. [E 1634.] Pyrite and blende, *scheiderz* from the Paz level of the Zancudo mine."

This is a mixture of a black, compact quartz with much blende, considerable pyrite and small quantities of galena. Large inclusions of trachyte are in some instances replaced on the outside by a fine granular mixture of sulphides and quartz. There is some evidence that much of the sulphides of the specimen have replaced angular trachyte fragments.

"170A. Concentrates called *Jaguas* from the Zancudo mine."

Jaguas are the highest grade of the five classes of concentrates from this establishment. According to Señor Don I. Gutierrez de Lara, they contain 50 per cent. quartz and 50 per cent. sulphides.

"171. [E 1072.] Ordinary ore from the Paz level of the Zancudo mine."

Like No. 169.

"172. Pyrites, galena and blende, *scheiderz* from the Zancudo mine."

"173. Pyrites, galena and blende, *scheiderz* from the Zancudo mine."

"174. [E 1635.] Ordinary ore to be broken and sorted into two qualities."

This is a quartz impregnated with sulphides, with zones of pure sulphides at contacts with an altered trachyte.

"175. [E 1075.] *Scheiderz* from others' workings in the Rosario and Paz levels of the Zancudo establishment."

This is an example of ores taken out by independent miners who lease the privilege of working those parts of the mine which are not profitable when worked in the regular manner.

This specimen is a trachyte breccia largely replaced by blende, galena and pyrite in quartz. The blende is in great excess.

"176. Pyrites and blende, *scheiderz* from the Chorros vein of the Zancudo establishment."

"178. Ordinary ore from the Chorros vein of the Zancudo establishment."

"179. *Scheiderz* from the Chorros vein of the Zancudo establishment."

"180. *Molino* ore from the Chorros vein of the Zancudo establishment."

"181. [E 1076.] Crystalized pyrite from the Chorros vein of the Zancudo establishment."

Here large pyritohedrons of pyrite occur on an altered trachyte. Blende crystals of the usual irregular form of later growth mingle with and partially cover the pyrite. Sharp crystals of blende of earlier growth occur in peculiar forms. Mingled with the quartz druse are needles of arsenopyrite.

"182. [E 1077.] Crystallized pyrites from the Paz level of the Zancudo establishment."

This pyrite has crystallized as pyritohedrons on altered trachyte and massive blende, accompanied by a quartz druse and dolomite crystals which run into siderite.

"183. [E 1652.] Crystallized pyrite from the Paz level of the Zancudo establishment."

"184. [E 1078.] Crystallized quartz and pyrite from the Paz level of the Zancudo establishment."

This is a quartz druse on altered trachyte, with massive pyrite and blende.

"185. Quartz and pyrite crystals from the Paz level of the Zancudo establishment."

"186. [E 1079.] Concentration matte from the Zancudo Smelting Works."

"187. Slag from concentration smelting from the Zancudo Smelting Works."

"189. [E 1080.] Rich slag from the Zancudo Smelting Works."

As these works are conducted according to modern practices, these products resemble similar ones of their class elsewhere.

"190. Litharge from the Zancudo Smelting Works."

"191. [E 2841.] Coal from the Zancudo Smelting Works."

This is a bituminous coal, of the variety known as *augenkohle.*

Extensive coal fields are mapped by Reclus in the vicinity of Amagá and Sabalétas.*

"192. Coke from the Zancudo Smelting Works."

"193. [E 1652.] Accretions from the Zancudo Smelting Works."

The other mines of the Titiribí district are in deposits of a different nature from those just described. They are on narrow dolomite veins in agglomerates and tuffs. The agglomerates are formed of coarse pebbles with some lava fragments, imbedded in a matrix of tuff. The tuffs are fresh in appearance except for an impregnation of pyrite. The ore occurs either in narrow veins, usually not exceeding an inch in width, or in a branching network of still smaller veins. The dolomite gangue carries blende and pyrite in quantity. As accessory minerals, crystallized dolomite, calcite and jamesonite, were observed. The latter was in considerable quantity in some of the specimens.

---

* "The Earth and its Inhabitants": South America, Vol. I, p. 200.

In all impregnations noticed among the ores of Titiribí and in other similar deposits of Colombia, the pyrite precedes the blende and appears first as small crystals scattered through the rock. Where the alteration has proceeded far, however, the blende usually much exceeds the pyrite in quantity. There frequently appear two generations of blende; one, small in quantity, is earlier than the major part of the pyrite and appears as sharp, well defined crystals; the other, forming the larger part of the blende, is in the usual semi-massive forms and irregularly bounded crystals overlying the pyrite and mingled with it. The few antimonial and arsenical minerals appear to be the latest of all. Jamesonite occurs in open cavities coating the sulphides. Arsenopyrite, which in some of the more northern districts is the principal ore, here occurs only as a druse of needle-like crystals coating pyrite.

It is well known that the minerals of the lavas, especially the basic ferromagnesian silicates, are unstable, and when exposed to the atmosphere alteration sets in almost immediately. When the minerals are broken up and deposited in the form of a porous tuff, this alteration is much favored and goes on with great rapidity. The decomposition of the basic lime-bearing feldspars and the ferro-magnesian silicates sets free the carbonates of lime and magnesia in quantities which are at times very considerable. In consequence of this the gangue mineral, which in the neighboring Zancudo mines is quartz, is in the deposits in tuff, dolomite. As the blende and pyrite were deposited contemporaneously with the dolomite, it is probable that these minerals also are derived from the decomposition products of the country rock, although it by no means necessarily follows. This deposit seems to be an example of a valuable deposit formed by a leaching of the rocks of the immediate vicinity. A further study in the field would be of much interest.

From the three mines not included in the Zancudo establishment Señor Gamba collected the following 19 specimens:

"195. Sandy material, from the Otramina mine."

"196. Veinstuff from the Otramina mine showing the thickness of the vein."

"197. [E 1081.] Veinstuff showing the thickness of the vein."

This is a half-inch vein of dolomite carrying blende and pyrites in a mineralized tuff which is thoroughly impregnated with sand-like grains of pyrite.

"198. Sandstone, wall rock in the Otramina mine."

Probably this is a volcanic "sandstone," *i. e.*, a tuff.

"199. Veinstuff from the Otramina mine."

"200. Conglomerate [*agglomerate*], wall rock of the Otramina mine."

"202. [E 1082.] Conglomerate [*agglomerate*], wall rock of the Otramina mine."

It is composed of quartz pebbles and lava fragments in a matrix of tuff.

"203. Sandstone [*tuff*] like No. 198."

"204. Rock intrusive in the sandstone of the Otramina mine."

"205. Quartz and pyrites from the Otramina mine showing an exceptional thickness of the vein."

The vein here varies from one-quarter inch to one and one-half inches in width and is between walls of a light colored tuff, similar to that of specimen No. 202. The vein consists almost wholly of blende and pyrite, with a little dolomite. In cavities occur small crystals of dolomite and cobweb-like forms of jamesonite.

"207. [E 1085.] Ore showing an exceptional width of the vein in the Otramina mine."

This specimen shows a width of six inches of branching vein. The vein here is brecciated like that of Zancudo. The veinstuff consists of blende and pyrite, with small quantities of dolomite enclosing fragments of tuff.

"208. [E 1084.] Ore from Cateador vein."

The formation is similar to that of the Otramina mine. The specimen is like No. 197 in width of vein, nature and appearance of veinstuff and attached country rock, but there is less dolomite gangue.

"209. Ore from the Cateador vein."

"210. [E 1097.] Ore from the Cateador vein."

Galena, pyrite and chalcopyrite, with dolomite, forming small irregular seams in tuff.

"211. [E 1098.] Ore from the Rose vein, same formation as at the Otramina mine."

A compact aggregate of pyrite and blende in about equal parts, with galena and some calcite and dolomite. The vein must be at least four inches wide.

"212. [E 1099.] Ore from Las Vetas mine, same formation as at the Otramina mine."

Pyrite in large pyritohedrons and blende, in about equal parts, with some galena and much jamesonite, the whole on a white gritty tuff.

"213. Ore from Las Vetas mine."

"214. [E 1100.] Ore from Las Vetas mine."

Massive sulphides of iron and zinc, in irregular branching veins in tuff, with crystals of calcite and dolomite.

"215. [E 1101.] Ore from Las Vetas mine."

Like N o. 214.

GOLD AND SILVER MINING DISTRICT OF CARAMANTA.

Caramantá, nearly upon the southern boundary between Antioquia and Cauca, is upon the western flank of the Cauca valley and therefore may be included among the mining districts of the Sierra del Choco, or Western Cordillera.

The ores occur, as nearly as may be judged from hand specimens, in trachytes and trachyte tuffs like those of the Otramina mine of Titiribí. The gangue is, however, calcite instead of dolomite and in places it is quartz. Mixtures of quartz and calcite in any quantities are not shown in the specimens, however. Antimony in the form of stibnite occurs in pockets in the tuff. Associated with the ores, according to Señor Gamba, are dioritic and syenitic porphyries, andesite and phonolite. One specimen in the collection is an altered trachyte.

From Caramantá Señor Gamba collected twenty-nine specimens representing three mines. The series is as follows:

"216. Dioritic porphyry."

"217. Syenitic porphyry."

"218. Andesite."

"219. Phonolite."

"220. Silver ore."

"221. Argentiferous galena."

"222. [E 1205.] Galena and blende, ore from the Condé mine."

This is a mixture of galena and yellow blende with a small quantity of calcite.

"223. [E 1206.] Galena and blende from the Condé mine," with calcite and quartz.

"224. Ordinary ore from the Condé mine."

"225. [E 1102.] Blende, ore from the Condé mine."

Seams of yellow blende and quartz in andesite.

"226. Galena, *molino* ore from the Condé mine."

"228. [E 1203.] *Molino* ore from the Condé mine."

"229. [E 1103.] Galena, *molino* ore from the Condé mine."

"230. [E 1104.] Galena, *scheiderz* from the Condé mine."

Granular blende and galena with coarsely crystalline calcite and an indeterminate chloritic gangue, form a vein three inches wide. Some chalcopyrite is present.

"231. Pyrite and galena, ore from the Condé mine."

"232. [E 1105.] Pyrite and galena, ore from the Condé mine."

This is a quartz impregnated with small crystals of galena, pyrite and blende. Tuff is enclosed in the form of angular fragments and streaks where the replacement has been incomplete.

"233. Pyrite and galena, ore from the Condé mine."

"234. [E 1106.] Black blende, ore from the Condé mine."

This is a fine granular blende with quartz.

"235. *Molino* ore from the Condé mine."

"236. Blende and pyrite, ore from the Condé mine."

"237. [E 1107.] Yellow blende on feldspathic veinstuff from the Condé mine."

This is a yellow blende with some granules of quartz and pyrite on coarsely crystalline calcite.

"238. Yellow blende on calcite."

"239. [E 3540.] Stibnite."

Typical radiated black stibnite forms a pocket in rhyolite tuff. Around the edges of this pocket are hollows where radiating stibnite crystals have been dissolved. Kermesite is present as an alteration product.

"240. [E 1108.] Quartzite."

This proves to be a trachyte which is much altered and impregnated with pyrite and with small amygdules partially filled with calcite. In its present condition it contains, as determined by analysis by the writer, 57.4% silica. Before the impregnation with pyrite and calcite the amount must have been somewhat larger as there has been little or no silica added during the alteration and impregnation.

"241. *Colorado* gold ore from the San Cayetano mine."

"242. *Colorado* gold ore from the San Cayetano mine."

"243. [E 1109.] *Colorado* gold ore from the San Cayetano mine."

"244. Decomposed pyrites, gold ore from the San Cayetano mine."

"245. Auriferous pyrites, ore from the San Cayetano mine."

"246. Auriferous pyrites, ore from the San Cayetano mine."

"247. Gold ore from the Zareimalito mine."

"248. Gold ore from the Zareimalito mine."

"249. Gold ore from the Zareimalito mine."

GOLD MINING DISTRICT OF MARMATO IN THE DEPARTMENT OF CAUCA, AND THE ECHANDIA SILVER MINES.

Marmato is situated on the west flank of the Cauca valley and on the slopes of the Marmato heights, which rise 2,230 feet above the river. It is a few miles south of the boundary of Antioquia in the department of Cauca. It is a very old mining camp and its mines have been worked with some interruption since 1634.

The Marmato deposits were described in 1826 by Boussingault as large veins of pyrite running east and west in a "porphyritic syenitic grünstein." An older account (1624) mentioned them as branching veins and pockets which were doubtless the weathered outcrops of the veins. Señor Gamba in the catalogue describes the wall rock as a quartzose porphyry (quartz-porphyry?) and the ores as pyrite and blende carrying gold.

Near Marmato upon the Loaiza Hill are the important silver mines of Echandía. The deposit is spoken of by Restrepo as a vein of auriferous silver, although from Señor Gamba's catalogue there would seem to be a number of veins. The ores are pyrite, blende, galena, argentite and native silver, which occur both in vein form and as impregnations of the rhyolites and their schistose alterations. The gangue is sometimes quartz, sometimes calcite, and frequently an ash-like substance that appears to be a decomposed rhyolite. The country rock, as determined by the writer from the specimens, is a light grey rhyolite.

Señor Gamba collected the following nineteen specimens from the Echandía mines:

"250. Porphyry, wall rock of all veins in the Echandía mines."

This specimen is not in the collection, but it is doubtless like the next specimen, a rhyolite.

"252. [E 1110.] Mineralized porphyry, silver ore from the Echandía mines."

A light grey rhyolite impregnated with galena, blende and pyrite. Cavities are lined with quartz crystals and carry wire silver.

"253. Pyrite, ordinary ore from the Echandía mines."

"254. Pyrite and blende, ore from the Echandía mines."

"255. Pyrite and blende, ordinary ore from the Loaizita lode, Echandía mines."

"256. [E 1111.] Mineralized schist with native silver, ore from the Loaizita lode, Echandía mines."

The mineralization is complete and little remains of the schistose altered lavas. The specimen consists of pyrite, galena and blende in a granular quartz gangue with numerous cavities which contain wire silver.

"257. [E 1112.] Galena and blende with wire silver, *scheiderz* from the Loaizita lode, Echandía mines." Like No. 256.

"258. Pyrite, galena and blende, ore from the San Antonio vein, Echandía mines."

"259 [E 1113.] Pyrite, *scheiderz* from the San Antonio vein, Echandía mines."

This is a cellular aggregate of pyrite crystals.

"260. [E 1114.] Pyrite and galena, *scheiderz* from the San Antonio vein, Echandía mines."

The gangue is quartz.

"261. [E 1115.] Pyrite and blende in quartz, ore from the San Antonio vein, Echandía mines."

It contains wire silver in cavities.

"262. [E 1116.] Galena and pyrite, with native silver and argentite, ore from the Loaizita lode, Echandía mines."

The native silver occurs abundantly, both encrusting the sulphides and as wire silver.

"263. [E 1117.] *Scheiderz* from the Loaizita lode, Echandía mines."

This consists of blende, pyrite and galena with native silver in quartz.

"264. [E 1142.] Quartz with native silver and argentite from the Loaizita lode, Echandía mines."

"265. [E 1118.] Galena, pyrite and blende in quartz, ordinary ore from La Plata vein, Echandía mines."

This specimen consists of granular sulphides in granular quartz and decomposed rhyolite.

"266. Quartz, ordinary ore from La Plata vein, Echandía mines."

"267. [E 2791.] Pyrite and blende, *scheiderz* from La Plata vein, Echandía mines."

The gangue is a mixture of quartz grains, with decomposed rhyolite.

Argentite is present in the form of small grains.

"268. Pyrite and blende, *scheiderz* from La Plata vein, Echandía mines."

"269. Galena, *scheiderz* from La Plata vein, Echandía mines."

"270. Galena, *scheiderz* from La Plata vein, Echandia mines."

From the gold mines of Marmato, Señor Gamba collected the following six specimens, representing three mines:

"272. Quartzose porphyry, wall rock of all veins in Marmato."
Quartz-porphyry, as used here, is equivalent to rhyolite.
"273. [E 1119.] Pyrite and blende, gold ore."
"274. [E 1120.] Pyrite and blende, gold ore."
These specimens are massive sulphides of iron and zinc.
"275. [E 1209.] Pyrite and blende, gold ore."
"276. [E 1647.] Pyrite and blende, gold ore."
This specimen has some decomposed rhyolite attached.
"277. Auriferous pyrites."

SILVER MINING DISTRICT OF SUPÍA, IN THE DEPARTMENT OF CAUCA.

A few miles southwest of Marmato, upon the Supía River, a branch of the Cauca, lies the town of Supía. The ores of the district are blende and pyrite, in "porphyry," associated with "trap" and andesite. They are overlain by a sandstone, which is probably of volcanic origin.

Here Señor Gamba collected the following twelve specimens, representing two mines:

"278. Porphyry, wall rock of the La Pava vein."
"279. Sandstone [*tuff*] overlying the porphyry."
"280. Andesite, from Carbunio, near Supía."
"281. Trappean formation in Supía."
"282. Sandy veinstuff from La Pava mine."
"283. Sandy veinstuff from La Pava mine."
"284. Blende and pyrite, ordinary ore from La Pava mine."
"285. [E 1134.] Blende and pyrite, ordinary ore from La Pava mine."
"286. Veinstuff with crystals of black blende, from La Pava mine."
"287. Pyrite and blende, *scheiderz* from La Pava mine."
"288. Pyrite and blende, *scheiderz* from La Pava mine."
"289. Ordinary ore, from La Pava mine."
"290. *Scheiderz* from La Pava mine."
"291. *Scheiderz* from La Pava mine."

SILVER AND GOLD MINING DISTRICT OF MANIZALES.

Manizales, founded in 1848, is a town of rapid growth, having, in 1880, 14,600 inhabitants. Mining is not the principal industry of the place, for it is the most important commercial center of Southern Antioquia, and has valuable farming and grazing interests. It is situated upon the boundary between Antioquia and the Department of Tolima, upon a terrace of the Sierra del Quindiu, or Central Cordillera of the Andes, and upon the northern bank of the Chinchina, a river which empties into the Cauca. The ores of this district, like the others of Southern Antioquia, consist largely of blende with pyrite. In addition, antimonial ores occur in the form of stephanite, brongniardite, tetrahedrite, and pyrargyrite. These ores occur in quartz and calcite. There is nothing about the specimens to indicate their mode of occurrence. The region is volcanic, and the specimens of country rock examined proved to be trachytes and rhyolites. Specimens of country rock from Manizales and vicinity are listed by Señor Gamba as "porphyritic syenite," "quartzose schist," "trachyte" and "tuffs." Of these, the "porphyritic syenite" proves to be a rhyolite, and the "quartzose schist" a trachyte. The term syenite is here, as elsewhere in Colombia, the local name given to some lava.

From Manizales Señor Gamba collected twenty-one specimens, representing six mines. The series is as follows:

"292. Syenite, wall rock of some of the veins."

This specimen, not being in the collection, could not be examined. For reasons given under the first specimen entered in the catalogue, this rock is here considered to be a trachyte.

"293. Decomposed quartzose ore from the Diamante mine."

"294. Decomposed quartzose ore from the Diamante mine."

"295. Quartz with pyrites, freibergite (argentiferous tetrahedrite) and ruby silver, from the Morisco mine."

"296. *Colorado* ore from the Diamante mine."

"297. [E 1121.] Porphyritic syenite, wall rock of the Morisco mine."

This is a light grey, very acid rhyolite, thoroughly kaolinized.

"298. [E 1122.] Antimonial silver from the Morisco mine."

This is a specimen of vein quartz, with druses of quartz lining cavities. Upon the walls of these cavities small spherical aggregates of stephanite are found.

"299. Antimonial silver ore, rich in brongniartine."

This mineral is a sulph-antimonide of lead and silver.

"300. Pyrite and brongniartine, gold ore from the Morisco mine."

"301. Gold ore from the Morisco mine."

"302. [E 1086.] Galena, *fahlerz* (tetrahedrite) and blende from the Contento silver mine."

The gangue is a decomposed trachyte.

"303. [E 1087.] Galena, *fahlerz* (tetrahedrite) and blende, siver ore from the Contento mine." (Like No. 302.)

"304. [E 1088.] Galena, *fahlerz* (tetrahedrite) and blende, silver ore from the Contento mine."

It is a compact mass of sulphides.

"305. [E. 1090.] Blende, *scheiderz* from the Contento silver mine."

In appearance this specimen is much like some which occur in southwest Missouri. The blende occurs as a cement in a breccia of a chert-like quartz. Where crystals have formed, they are of the bright red variety, known in the Missouri zinc districts as "ruby jack."

"306. Blende, silver ore from the Contento mine."

The blende occurs as a cement in a trachyte-breccia, and in stalactitic forms in cavities. Attached to the specimen is some of the wall rock, which is too much altered for exact determination. It was, however, either an andesite or a trachyte, probably the latter.

"307. Gold quartz from the Pinares mine."

"308. [E 1091.] Quartzose schist, wall rock in the Volcanes mine."

This proves to be light grey trachyte, kaolinized, and slightly impregnated with pyrrhotite.

"309. Quartzose schist, wall rock in the Volcanes mine."

The rock called quartzose schist in this district corresponds to a trachyte. (See No. 308.)

"311. Ore from the Tolda Fria mine, showing the thickness of the rich vein.

"312. Ore from the Tolda Fria mine, showing the thickness of the rich vein.

The Tolda Fria mine is in the Department of Cauca, about ten miles (three leagues) from Manizales.

"313. [E 1092.] Ore showing the thickness of the rich vein at the Tolda Fria mine, near Manizales."

This is a section across a quartz vein, varying from one-half to one inch in width, and enclosed in a black talcose selvage. The ores consist of small pyrite crystals, sparingly distributed along the comb of quartz.

"314. [E 3539.] Stibnite from Manizales."

This stibnite occurs with pyrites on quartz.

From South Central Antioquia, outside of Manizales, Señor Gamba collected the following specimens:

"315. [E 1093.] Ruby silver, ore from the Bureo mine, Pacora."

Pacora is upon the Central Cordillera, fifty kilometers north of Manizales. The specimen consists of pyragyrite in quantity, imbedded in calcite and some pyrite.

"316. [E 1094.] Ruby silver, ore from the Bureo mine, Pacora."

Pyragyrite and calcite, as in No. 315, are imbedded in a decomposed trachyte.

"317. Ruby silver, ore from the Bureo mine, Pacora."

"318. Syenite from Yotombil, near Manizales."

"319. Trachyte from the Aguatal road from Manizales to Tolima."

"320. Tuffs from Aguacatæ."

THE MINING DISTRICTS AND ORES OF TOLIMA.

The Magdalena River, from its source two degrees north of the equator, to about six degrees north where it touches the Departments of Antioquia and Cundiamarca, flows in a deep, longitudinal valley, between the Eastern and Central Cordilleras of the Andes. This valley, between the crests of the two Cordilleras, and between the above indicated north and south limits, forms the Department of Tolima, the second in importance of the mining states of Colombia.

According to John C. Randolph,* who has studied the geology of this region, the Magdalena flows in a synclinal valley. Under the alluvion of the valley lies a red Triassic sandstone which overlies Archæan schists. The schists outcrop in a broad zone at an elevation of between 4,000 and 5,000 feet. On the west side of the valley patches of Jurassic limestone overlie the sandstone in places, and on the east these Jurassic limestones are of great thickness. The schists are penetrated and overlain everywhere with andesites and other eruptive rocks. In the collection under consideration these eruptives are represented by andesites, trachytes and rhyolites.

Mr. Randolph found that the veins of Tolima are quartz intercalated in the schists. The veins tend to wedge out and reappear. No true vein cutting across the schists has been found. The collections in the Museum show in addition to this that the ores, although often occurring in the mica schists, are found only in the vicinity of eruptive rocks.

In the early days of mining in the Department of Tolima the cities of San Sebastian de la Plata in the south, and Mariquita in the north, were the centers about which the mining districts were grouped. From a variety of causes, including attacks from hostile Indians and the prohibition of enforced Indian labor, the mines were abandoned for many years, and even the locations of many of them were forgotten. From the localities given by Señor Gamba in his catalogue, it appears that the revival of mining in recent times has taken place almost wholly in the northern districts, in the vicinity of the active volcano of Tolima. These districts were of old, tributary to the cities of Mariquita and Ibague. The volcano of Tolima, according to Reclus, is an andesite cone upon a base of mica schist and slate. The mines are in part in andesites, other acid eruptives and their derivatives, which came from Tolima and various old vents of the vicinity, and in part in the underlying crystalline schists and slates. In the latter the ores tend to become poor for causes which will be explained later. The ores yield an auriferous silver and from them many secondary auriferous gravels have been derived. The minerals of these ores, like those of the Zancudo mines of Titiribí and Sabalétas, are mostly blende, which occurs with smaller, but yet considerable, quantities of galena and pyrite. Arsenical minerals are rare, but antimonial ones common. Pyrargyrite is a common ore. These minerals occur principally in quartz veins, but much calcite occurs in the gangue in places and there are deposits in which brecciated country rock is the principal veinstuff.

---

*Tr. A. I. M. E. Vol. XVIII, 1889, p. 208.

While some of the mines now in operation were reopened as early as 1785, many of them appear to be of very recent origin, as the towns in which they are located are not yet on the maps or mentioned in any works on the subject which are available.

Mariquita, about ten miles west of the important city of Honda, is in the extreme northern part of Tolima. It lies on a plain in the valley of the Guari, which flows into the Magdalena from the west, and in the angle formed by the meeting of a ridge of the Central Cordillera, running east and west, with one running north and south. It was founded, according to Vicente Restrepo, in 1551, on account of the mines, and speedily became a very wealthy and important city of 20,000 inhabitants. With the decay of the mines its importance decreased, until it is now (as described by Reclus) an unimportant place of 5,000 inhabitants. The tributary mining districts stretched, in former times, for long distances to the south and east. Of these districts, only those of Santa Ana, Frias and Venadillo continued working mines in 1893, and consequently only these are represented in the collections. It is not unlikely, however, that some of the new districts may lie upon the site of the forgotten older districts. The chief product of the region is an auriferous silver. The placers are said to be rich in gold, probably from the decay of the auriferous silver deposits.

GOLD MINING DISTRICT OF SOLEDAD.

This appears to be a new district, as it is not to be found upon the maps, nor is it mentioned in any of the literature upon the subject which is readily accessible. It is known, however, that it is in the extreme northern part of Tolima, in the territory formerly tributary to Mariquita. The ores are auriferous quartz and pyrite, with argentiferous galena. These occur in quartz veins in a black talcose schist. The ore and wall rock appear in the specimen examined very like those of Tolda Fria. Associated with the schists are andesite and "porphyritic andesite." From Soledad Señor Gamba collected the following twelve specimens :

"320. Andesite from near Soledad."

"321. Porphyritic andesite from near Soledad."

Probably an andesite with scattered coarse phenocrysts.

"322. [E 1095.] Quartz and schist, gold ore from near Soledad."

A quartz vein varying from one-half to one inch in width, containing scattered grains of pyrite, and enclosed in a black talcose schist.

"323. Quartz and schist, gold ore from near Soledad."
"324. Galena, ore from the Tulcan mine."
"325. Stibnite."
"326. Gold ore."
"327. Gold ore."
"328. Gold ore."
"329. Quartz and pyrite, gold ore."
"330. Quartz, gold ore."
"331. Schist impregnated with pyrites."

GOLD MINING DISTRICT OF SUCRE.

As with Soledad, Sucre, a new district, is not to be found on the map. It probably lies near Santana. The ores are quartz with arsenopyrite in slate.

From the Sucre district Señor Gamba collected the following five specimens, representing one mine :

"332. [E 1096.] Black quartzose slate, wall rock of the Sonrisa mine, Marulandes."

This is a hard, clean slate, with well developed cleavage. In quality it is an average roofing slate.

"333. Black quartzose slate, wall rock of the Sonrisa mine, Marulandes."

"334. Quartz with arsenopyrite from the Sonrisa mine, Marulandes."

"335. Quartz with arsenopyrite from the Sonrisa mine, Marulandes."

"336. Quartz with arsenopyrite from the Sonrisa mine, Marulandes."

SILVER MINING DISTRICT OF SANTANA.

Santana or Santa Ana, five miles southwest of Mariquita, was reputed in the early days of Colombian mining to be one of the richest districts tributary to that city. After the general closing of the mines at the beginning of the 18th century, these mines lay hidden until they were rediscovered and opened by order of the Spanish government in 1785. From then until now they have been worked at intervals. One of the richest of the old mines was the Santana mine. According to Vicente Restrepo, this mine, with three others in the district, was operated under government control from 1785, when it was rediscovered, until 1796, when it was abandoned as unprofitable. It appears to have been neglected again until 1824, when it was leased to private parties and operated with European machinery and management. For fifty years, or until 1874, mining was carried on by three companies successively, none of whom were repaid for the expenditures required. In 1874, when the mine was again abandoned, there were two shafts, one down 600 feet and the other 900 feet, and at these depths the ore became very poor. In connection with other observations this fact points toward a rather interesting conclusion: These Cordilleras are composed of eruptive rocks set upon a base of crystalline and metamorphic schists including (near Santana and the volcano of Tolima) mica schist and slate which are flanked by Triassic sandstones. From nearly every mine mentioned in this catalogue there come specimens often disguised under local names, which are either andesites, rhyolites, trachytes, dacites or their derived tuffs. In the case of the great majority of these mines no other rocks are mentioned, except more basic eruptives in very small quantities. The ores from the Titiribí district appear to be a product of a lateral leaching of surrounding lavas. If the other deposits in the lavas were similarly formed it would be expected that as the mines penetrated through the lavas into the crystalline rocks below, the ores would diminish in value even though the vein itself continued. It can now be stated definitely that the mines of Santana have penetrated to the underlying crystalline rocks, for besides the statement by Humboldt that the deposits of Santana form a bed in gneiss, there are among the specimens from the mines of the various Mariquita districts a slate, a gneiss, a mica schist and a limestone, showing that the mines are now below the lava. The ores consist of pyrite, galena and blende in quartz. The wall rock is given by Señor Gamba as schist, associated with granite and "porphyry."

One of the ancient mines, now long abandoned, is described in an old report* as an 18-inch vein of quartz with a dip of 45 degrees carrying native silver. Included in the Santana mining district are the mines of the neighboring town of Guayabal, a place of 5,000 inhabitants, about five miles southeast of Santana in the Sabanadija valley.

From the Santana district Señor Gamba collected the following twelve specimens:

"337. Granite from the road from Sucre to Santana."

"338. Porphyry from near Santana."

"339. [E 1123.] Quartz and pyrite, ore from Santana."

The black chlorite schist that appears to be common in these ores accompanies this specimen.

"340. [E 1124.] Quartz and pyrite, ore from Santana."

Galena and blende occur with these minerals.

"341. Galena and pyrite from Santana."

"342. Pyrite on quartz from Santana."

"343. Pyrite on quartz from Santana."

"344. Schist from the wall rock of the Calamonte mine, Guayabal."

"345. Pyrites and galena from the Calamonte mine, Guayabal."

"346. Pyrites and galena from the Calamonte mine, Guayabal."

"347. Pyrite, galena and blende, *scheiderz* from the Calamonte mine, Guayabal."

"348. Ordinary quartzose ore from the Calamonte mine, Guayabal."

THE FRIAS MINE.

The Frias mine of Guayabal near Santana is one of those which were worked by the Spaniards in the 17th century. At that time it had a great reputation, ranking with the Santana and the La Manta, among the richest silver mines in Colombia. The mine was abandoned early in the 17th century. It was rediscovered about 1871 and operated by an English company. According to the superintendent of the mine, in 1886 the ores, with an average yield of 311.4 ounces silver tothe ton, were "argentiferous sulphides of lead, a zinc combined with iron and arsenical pyrites; the sulphide of silver is frequently found and at times red silver and native silver." According to the same authority the gangue is quartz with calcite and siderite. The veins vary in width from a few inches to several feet and occur in micaceous and talcose schist. One of the specimens in the collection is a typical mica schist, and Señor Gamba catalogues a limestone and a gneiss from the vicinity. It is to be inferred from this that the mine is located below the eruptives and in the basal crystalline rocks. In 1886 the mines had reached a depth of 600 feet. Pyrargyrite, referred to above as "red silver," is abundant in the specimens of the Museum collection. According to John C. Randolph all the ores are found at the intersection of a seam with the main vein.*

---

* Don Jose D'Eluyar, 1785.

From the Frias silver mine Señor Gamba collected the following thirty-two specimens:

"349. [E 1656.] Blende and galena, *scheiderz*."

This specimen consists of bands of coarse blende, coarse galena, fine granular pyrite and a finely granular mixture of galena and pyrargyrite.

"350. [E 1653.] Galena impregnated with ruby silver."

This is a mixture of massive galena and pyrargyrite in about equal quantities. Crystals of pyrargyrite are found upon the granular mixture.

"351. [E 1126.] Rich galena."

This galena is mixed with some blende and much pyrargyrite.

"352. [E 1129.] Galena and blende in calcite."

This is a mixture of galena, blende, and pyrite on calcite with crystals of blende and galena.

"353. Pyrite, galena and blende, *scheiderz*."

"354. [E 1127.] Mineralized schist."

This is a mixture of galena, blende and pyrite in quartz veins which traverse a graphitic mica schist.

"355. [E 1128.] *Scheiderz*."

This is a coarsely granular mixture of about equal parts of galena, blende and pyrite.

"356. Concentrates, different sizes."

"357. Concentrates, different sizes."

---

* Tr. A. I. M. E., Vol. XVIII, (1889) p. 205.

"358. Concentrates, different sizes."

"360. Gneiss from near the Frias mine."

"361. Limestone from near the Frias mine."

"361–1–20. Twenty specimens of native silver and argentite."

GOLD MINING DISTRICT OF LIBANO.

The town of Libano, about fourteen leagues (forty-two miles) southwest of Honda and eight leagues (twenty-four miles) west of Ambalema, lies at an elevation of 3,500 feet. The mines are about three leagues (nine miles) south of the town. There are two deposits, the La Plata veins and the Esperanza veins. Each consists of a group of quartz veins in mica schist, all approximately parallel and with a northwesterly strike. There have been a number of shafts sunk on different veins of the series.*

The wall rock as shown in the collection is the "*negro-negro*" black schist instead of the mica schist mentioned by Mr. Pierce.

The ores are blende with galena, pyrite and some chalcopyrite which at the outcrops carry silver and in depth gold.

From the Libano district Señor Gamba collected the following seven specimens, representing one mine:

"362. Black schist called 'negro-negro,' wall rock of La Plata del Libano mine."

"363. Pyrite and blende, ore from La Plata del Libano mine."

"364. Quartz, ore from La Plata del Libano mine."

"366. Ordinary quartzose ore from La Plata del Libano mine."

"367. Ordinary quartzose ore from La Plata del Libano mine."

"368. [E 1130.] Ordinary quartzose ore from La Plata del Libano mine."

The quartz contains pyrite, galena and blende.

THE CHINA RIVER GOLD AND SILVER MINING DISTRICT.

The China river is not to be found on any of the maps which were consulted. From Restrepo's account, in which the deposit is briefly described as a "silver vein," it seems to be not far from the city of Ibague. According to the catalogue the ore is galena, pyrite and blende in quartz. The wall rock appears to be chlorite schist, since the "hornblende rock" of this region proves to be such in the specimens in the Museum collection. With this is associated andesite and the rock described by Señor Gamba as "syenite." Señor Gamba collected in the China river region nineteen specimens representing three mines. The series is as follows:

---

*Wm. Pierce, Tr. A. I. M. E., Vol. XVI., p. 301, 1889.

"369. Syenite from the China river."

"370. Hornblende, wall rock of the vein."

These specimens, which are not in the collection, by analogy with specimens of like name are considered to be andesite or trachyte and the schistose chloritic rocks derived from them.

"371. Decomposed ore."

"372. [E 1131.] Quartz and pyrite from the Santander lode."

This is a rusty quartz with pyrite in large crystals and some blende and galena.

"373. *Colorado* ore from Santander lode."

"374. Quartz, ore from the Boyala lode."

"375. [E 1204.] Quartz and pyrite, ore from the Boyala lode."

"376. [E 1132.] Rich decomposed ore from the San Sebastian lode."

A honeycombed quartz with no visible silver-bearing minerals.

"377. Ordinary quartzose ore from the San Sebastian lode."

"378. Pyrite, blende and galena, *scheiderz* from the San Sebastian lode."

"379. Pyrite, blende and galena, *scheiderz* from the San Sebastian lode."

"380. [E 1202.] Galena, *scheiderz* from the San Sebastian lode."

About 15% of the specimen is pyrite.

"381. [E 1201.] Rich galena, *scheiderz* from the San Sebastian lode."

The galena is mingled with about 5% of pyrite and occurs in quartz. The galena is very finely granular and contains pyrargyrite.

"382. Pyrite and blende, *scheiderz* from the San Sebastian lode."

"383. [E 1200.] Pyrite and blende, *scheiderz* from the San Sebastian lode."

"384. [E 1199.] Pyrite and blende, *scheiderz* from the San Sebastian lode."

The galena is finely granular and contains pyrargyrite in quantity.

"385. Andesite from the China river."

"386. Andesite from the China river."

SILVER MINING DISTRICT OF VENADILLO.

Venadillo, on the Venadillo river, is southwest of the city of Ambalema and northeast of Ibague. Gold was obtained from placers on the Venadillo river at a very early date and by 1625 the place which had become an important mining center, was practically deserted because of depredations of hostile Indians. The first account of the recent workings is by Restrepo, who reports in 1886 that some miners from Antioquia had extracted gold there "within the last few years." This gold was evidently obtained from placers and the silver mines were opened later. The ore is pyrite and galena in quartz. From Venadillo, Señor Gamba collected the two following specimens, representing one mine:

"387. Pyrites and galena, *scheiderz* from the Palmillo mine."

"388. Pyrites, ore from the Palmillo mine."

GOLD AND SILVER MINING DISTRICT OF IBAGUE.

Ibague, the capital of Tolima, is situated at an elevation of 4,270 feet on a plain which is surrounded by spurs from the volcano of Tolima. It is on the banks of the Combeima, an affluent of the Magdalena river. The crater of Tolima is twenty miles to the northwest. The population of Ibague is, according to Reclus, 13,000, and according to another estimate, 10,000. As the important interests of the city, like those of Manizales, are other than mining, the size of the place is no index of the importance of the mines. Founded in 1551, at the same time as San Sebastian de la Plata and Mariquita, it was for many years the center of an important mining industry which nearly disappeared with the general decline of mining in Colombia at the close of the sixteenth century. The ores, like those of the other districts of Northern Tolima, are sulphides of iron, lead and zinc in quartz. The zinc is the most abundant and the lead the least. The richer ores contain tetrahedrite and in most respects closely resemble those of the Santana districts. Tolima is an andesite cone on a pedestal of mica schist and slate. The mica schist and slate are reached in the Frias, Sonrisa and other mines of the Marequita districts. The ores of the Ibague are in andesite and its schistose chloritic alteration products. The local names of the rocks in which the ores occur are syenite, granite, hornblende, schist and black or "*negro-negro*" schist. These schists are chloritic, schistose and metamorphic andesites. Granite and syenite appear to be old local names for dacite and andesite.

From the Ibague district Señor Gamba collected thirty-three specimens, representing seven mines. The series is as follows:

"389. Quartz and pyrites, ore from the Triumfo mine, near Ibague."

"390. [E 1198.] Quartz and pyrites, *scheiderz* from the Triumfo mine, near Ibague."

The quartz contains pyrite and blende in about equal quantities.

"391. [E 1133.] Pyrites and galena, *scheiderz* from the Triumfo mine, near Ibague."

With the pyrite and galena which occur in quantity there is much blende.

"392. Hornblende schist, wall rock in the Floresta mine."

"393. Granite from near the Floresta mine."

As elsewhere in this catalogue, granite is here probably a synonym for dacite.

"395. Black (*negro-negro*) schist from the Floresta mine."

"396. Quartz, ore from the Floresta mine."

"397. Quartz, ore from the Floresta mine."

"398. Quartz, ore from the Floresta mine."

"399. Quartz, ore from the Floresta mine."

"400. Quartz, ore from the Floresta mine."

"401. Quartz, ore from the Floresta mine."

"402. Quartz, ore from the Floresta mine."

"403. Schist from the wall rock in the Gallo mine."

"404. Quartz, ore from the Gallo mine."

"405. [E 1135.] Quartz, ore from the Gallo mine."

"406. [E 1135.] Quartz, ore from the Gallo mine."

"407. Quartz, with gray copper (*tetrahedrite*)."

"408. Quartz, ore from the San Cayetano mine."

"409. Quartz, ore from the San Cayetano mine."

"410. Quartz, ore from the San Cayetano mine."

"411. [E 1136.] Quartz and pyrite, ore from the San Cayetano mine."

"412. *Colorado* ore from the San Cayetano mine."

"413. Syenite from Ibague.

As used here, "syenite" is probably synonymous with andesite.

At Anaime, a town of which nothing could be learned, Señor Gamba secured specimens from three silver mines. The specimens now in the collection are from a deposit of tetrahedrite and quartz in mica schist and andesite tuff, which the miners know as "syenite." From this town come also specimens of a quarter-inch seam of cinnabar in mica schist. The town Anaime, near the river of the same name in the Department of Cauca, although not very far distant, does not appear to be the place referred to here. From Anaime Señor Gamba secured the following specimens:

"414. [E 1137.] Schist, wall rock in the Recreo mine, Anaime."

This specimen is a mica schist with pockets and seams of calcite and with large isolated pyrite crystals scattered through it.

"415. Quartzose ore from the Recreo mine."

"416. Quartzose ore from the Recreo mine."

"417. [E 1138.] Quartz with *fahlerz* (*tetrahedrite*), ore from the Recreo mine."

A clean white quartz with nodules of tetrahedrite from one-half to one inch in diameter.

"418. Syenite from the Bolivar mine."

Though the specimen of this number is not in the collection, there is little doubt but it is the same rock as the following specimen, *i. e.*, rhyolite tuff.

"419. Syenite from the Bolivar mine."

"420. [E 1139.] Decomposed rich ore from the Bolivar mine, Anaime."

This is a comparatively fresh rhyolite tuff. As nine grams when tested did not yield even so much as a trace of the precious metals, there is some mistake about this specimen. It is probably specimen number 418, "syenite." It is a very acid rock even for rhyolite and contains, according to an analysis by the writer, 78.97% silica.

"421. Arsenical pyrites, ore from the Bolivar mine."

"422. [E 1210.] Cinnabar, mercury ore from Anaime."

"423. [E 1211.] Cinnabar, mercury ore from Anaime." Like No. 422.

These specimens are a quarter-inch vein of bright, crystalline cinnabar in mica schist. The vein lies in the plane of lamination of the schist.

"424. Cinnabar, mercury ore from Anaime."

"425. Native copper from Natagamia."

A mass which weighs eleven pounds. Natagamia, a place of 9,000 inhabitants, on the west bank of the Magdalena river, is the geographical center of Tolima. Native copper is said to occur at the Frontino mines of Antioquia, and there are accounts which, however, need confirmation, of copper ores in a number of places.

THE GOLD AND SILVER MINING DISTRICTS OF PAMPLONA, IN THE DEPARTMENT OF SANTANDER.

Among the collections of the Museum, there is a series of thirty-eight specimens representing the Baja and Vetas groups of mines near the city of Pamplona, in Santander. The Alta group near the same city is not represented. These specimens were exhibited at the World's Columbian Exposition by Colombia, and later were donated to the Museum; but the series is not a portion of the Gamba collection. For this and other reasons (*vide infra*), it may be inferred that the mines were not in operation in 1892. Indeed, this series differs from the Gamba collection in important respects. The specimens are small and choice, and appear to represent the richest ores only. There are no specimens of associated rocks and minerals, and no account of the region accompanies them. In the absence of data accompanying the collection, the following account has been taken from various sources, chiefly from Vicente Restrepo: Etude sur les Mines d'Or et d'Argent de la Colombie:*

Pamplona, Lat. 7° 20′ N., Long. 72° 45′ E., a city of 11,000 inhabitants, "stands at an elevation of 7,550 feet, in an old lacustrine basin, the source of the Rio Pamplonita." It is in the East Central part of the Department of Santander, only twenty miles from the Venezuelan frontier. It was founded in 1551, and early became very wealthy, from the large quantities of gold and silver obtained from its mines. With the subsequent decay of the mining industry came its decline, until now several of the neighboring cities are much larger. Soon after it was founded exceedingly rich placers were discovered, for which the district became famous; but the richest were exhausted in a few years. Soon after, gold and silver bearing veins were discovered at the Alta and Baja Montuosa, now known as Alta and Baja, and at the Vetas, all being districts west of the city. During the seventeenth century these mines were very celebrated, but were even then on the decline. In 1776 only placers were worked. In 1820 the mines were found to be completely abandoned. Since that date one or more mines at Alta, Baja and Vetas have been worked at intervals, but usually without any continued success. As Señor Gamba did not include these districts in his collections, it may be inferred that in 1892 no work was being carried on.

---

*The French edition treats the mines of Santander at much greater length than does the English version.

The veins are of blue quartz, traversing a rock described as essentially feldspathic, which alternates with a diorite, and sometimes with a granite. These veins vary in width from one to four centimeters, and rarely attain a width of ten or fifteen centimeters. The ores from some of the mines were described as sulphides of silver, zinc, antimony, lead, and iron. According to Boussingault, placers occur in a decomposed schist at the base of a "bed" of a schistose micaceous gneiss. The specimens in this collection do not throw any light upon the nature of the above-mentioned "*roche essentiellement feldspathique*," nor are there any specimens of diorite, granite, or other country rocks. The gangue is a very dark "blue quartz" in most specimens. In some there is a light-colored quartz. The only accessory mineral noted was aragonite coating quartz. The metalliferous minerals, occurring in these specimens, are pyrite, pyrrhotite, chalcopyrite, blende, enargite, freibergite, malachite, azurite, native gold, and native silver. For further information upon this subject the reader is referred to the work of Vicente Restrepo above cited. An article upon Pamplona, by Carl Degenhardt, in the Monatsberichte über die Verhandlungen der Gesellschaft für Erdkunde zu Berlin, 1842, contains a map of the Baja district.

GENERAL CONCLUSIONS.

The gold and silver ores of Colombia occur either in the acid lavas, which have been erupted at intervals from the close of the Tertiary to the present time, or in Archæan schists in the immediate vicinity of the lavas. In the schists they are usually poor in depth. Owing to the action of the heavy tropical rains, the weathered zone of the deposits has often been greatly enriched, and it was such enriched deposits that gave the immense yields of the early days of Colombian mining. The absence of specimens in this collection from such enriched zones, and the general excess of sulphide over oxide ores, indicate that the mines are in general sunk below this zone. Many of the sulphides in the collection are exceedingly rich, and come from deposits that carry large quantities of the precious metals at depths to which no surface enrichment could possibly reach.

The ores of Colombia are of two classes, those occurring in quartz in fissure veins of the ordinary type, and those formed by segregation from the surrounding rock. The fissure vein deposits are those of North-Central Antioquia, and present no feature of especial interest. The other deposits, formed by segregation from the surrounding lavas, differ in character according to the nature of the material in which they occur. In all deposits of the second class, the prevailing sulphide is blende. Those in andesite and other lavas have a quartz gangue, and are of metasomatic origin. Some, if not all, are in brecciated zones, in which the fragments are both replaced by and cemented with the ore-bearing quartz. All stages of replacement may be traced in the specimens. The ores in the tuffs form the most interesting class. They differ much from the above-mentioned deposits, although the two kinds sometimes occur within a few miles of each other. The tuffs, formed of comminuted lavas, decompose very rapidly, especially under the influence of the hot, acid waters, which accompany volcanic eruptions and often persist for many years after. The decay of the ferro-magnesian and lime-bearing minerals of the tuffs forms, as the gangue of these ores, sometimes dolomite and sometimes calcite.

The veins are very narrow and irregular, one of the most important reaching a width of less than two inches. Often in place of a single vein there is a zone of branching dolomite or calcite threads in the tuff. These features are evidence of a deposit formed by a leaching of the surrounding tuff.

In Tolima many of the ores occur in quartz in mica and chloritic schists of Archæan age, but always in the vicinity of one of the acid lavas. Mr. John C. Randolph says that these veins are narrow, that they are always intercalated with the schist and never cut it. They pinch out and reappear. Add to this their general tendency to grow poor in depth and their association with the lavas which furnish the metals for the deposits above mentioned, and it seems probable that these deposits are the result of a downward flow of waters which have leached the overlying eruptives. It appears that except for the vein deposits of North Antioquia, the precious metals, in the districts here considered, came to the surface in the lavas from which they have been leached. This leaching may have been done by hot solfataric waters following the eruption, or may have been the result of the abundant tropical rains. In either case the deposits would, as observed, be richer nearer the surface. This original greater richness at the surface when increased by the secondary enrichment of the oxidized zone through weathering, as described by several observers, accounts for the wonderful richness at the surface found by the original miners.

LITERATURE.

The following is a list of the more valuable of the recent works bearing upon the geology and mineral resources of Colombia, together with some of the more useful older works. The value of many of these has been judged necessarily only by the title, for I have not been able to consult all. Those which I have been able to consult are marked with an asterisk. References to the bibliographies of the region are included in the list:

Ueber den Salzquellen des Nördlichen Theilesper Provinz Antioquía und die Gebirgsformation der Umgebung von Medellin im Freistaate von Neu Granada. Karsten. *Archiv f. Min. XII, 1839.*

Pamplona, Colombia. Carl Degenhardt. *Monatsberichte über die Verhandlungen der Gesellschaft für Erdkunde zu Berlin. 1842.* This contains a map of the Baja District of Pamplona.

*Metallic Wealth of the United States. J. D. Whitney. *Philadelphia, 1854, pp. 109, 193.*

*Die Geologische Uebersichts Karte des mittlerern Theiles von Süd America. F. Fotterle. *A map from Petermanns Mitt. (?). Vol. II, 1856.* The colors have faded, and not much can be made out from it.

*Metalliferous Minerals and Mining. Davies, p. 284. This refers to the mercurial deposits.

Die Geognostichen Verhältnisse in Neu Granada. Herman Karsten. *Verhandlungen der Versammlung deutscher Naturforscher. Wien, 1856.*

M. Pissis. *Ann. des Mines, 5 m. Ser. Vol. IX, 1856, p. 81.*

David Forbes. *Quart. Jour. Geol. Soc., Vol. XVII, p. 7.*

*Carta Corographica del Estado del Cauca, por Manuel Ponce de Léon. *Bogotá, 1864.*

*On the Existence of Gold-bearing Eruptive Rocks in South America, which have made their appearance at two very distant Geological periods. David Forbes. *Rep't Br. Ass'n Adv. Sci., 1865, p. 52.*

*Notes on the Geology and Mining of the United States of

Colombia. Robert B. White. *Rep't of the Br. Ass'n Adv. Sci., 1882, p. 552.*

*Lithological Studies. A Description and Classification of the Rocks of the Cordilleras. M. E. Wadsworth. *Mem. Mus. Comp. Zoöl., Vol. XI, 1884, pt. 1.* This work when consulted proved not to bear upon the subject in hand, but to be a treatise on meteorites. This title is included here to prevent others from being misled by it.

*The Cauca Mining District. John Hays Hammond. *Tr. A. I. M. E., Vol. XIII, 1885, p. 135.*

Geologie de l'ancienne Colombie bolivarienne, Venézuela, Nouvelle-Grenade et Ecuador. H. Karsten. *Berlin, 1886.* With bibliography.

*A Study of the Gold and Silver Mines of Colombia. Vicente Restrepo. *Colombian Consulate, New York, 1886.*

Die Sierra Nevada de Santa Marta und die Sierra de Perijà. W. Sievers. *Zeitschrift der Gesellschaft für Erdkunde zu Berlin. Bd. XXII, 1888.* With bibliography.

*Notes on the Republic of Colombia, S. A. John C. Randolph. *Tr. A. I. M. E., Vol. XVIII, 1889–90, p. 205.*

*Etude sur les Mines d'Or et d'Argent de Colombie. Vicente Restrepo, with notes by Henry Jahlhay. *Bruxelles, 1891.* This is abridged from the larger Spanish edition. It is in places more complete than the edition in English.

*Colombia. *Bull. No. 33 of the Bureau of American Republics, Washington, D. C., 1892.* See also the monthly bulletins of this bureau.

Die Kordillere von Bogotá. A. Hettner. *Petermann's Mitt., 1892.* With bibliography.

Reisen in Süd-Amerika. Geologische Studien in der Republik Colombia. Reiss and Stübel, *Berlin, 1892.* With bibliography.

*Colombia. *Mineral Industry for 1892, Vol. 1, p. 557, N. Y.*

*Gold Washing in Colombia: Charles Bullman. *Engineering and Mining Journal, April 4, 1892.* Other articles on Colombia appear at intervals in this magazine.

*The Mineral Industry for 1893. *Vol. II, p. 330. N. Y.*

The Mineral Wealth of Colombia. *The Mining Journal, August 18, 1894, p. 901.*

*The Earth and Its Inhabitants: South America, Vol. I. The Andes Regions. Elisée Reclus. *New York, 1894.*

*The Mineral Resources of Colombia: Robert B. White. *The Mineral Industry for 1895. Vol. IV, p. 634.*

*Geology: Chemical, Physical and Stratigraphical. Vol I, p. 306. Joseph Prestwich. *Oxford, Eng., 1896.*

*The Manganese Deposits of the Department of Panama, Republic of Colombia: Eduardo J. Chibas. *Tr. A. I. M. E., Vol. XXVII, 1897, p. 63.* This article contains a *resumé* of the geology of the country.

Mining Districts of Colombia: Henry D. Granger and Edward B. Treville. *A paper read before the Atlantic City meeting of the Am. Inst. Min. Eng., Feb., 1898.* A brief abstract appears in the **Eng. and Min. Journal, Vol. LXV, 1898, p. 221.*

La Republique de Colombie: Ricardo Nunez and Henry Jahlhay. *Bruxelles, 1898.*

*An Outline of the Gold Fields of Colombia, South America: Francis G. Nichols. *Engineering and Mining Journal, Vol. LXV, 1898, p. 520.*

*The Darien Gold Mining Region of Colombia: E. J. Chibas. *Engineering Magazine, Vol. XVI, 1898, p. 49.*

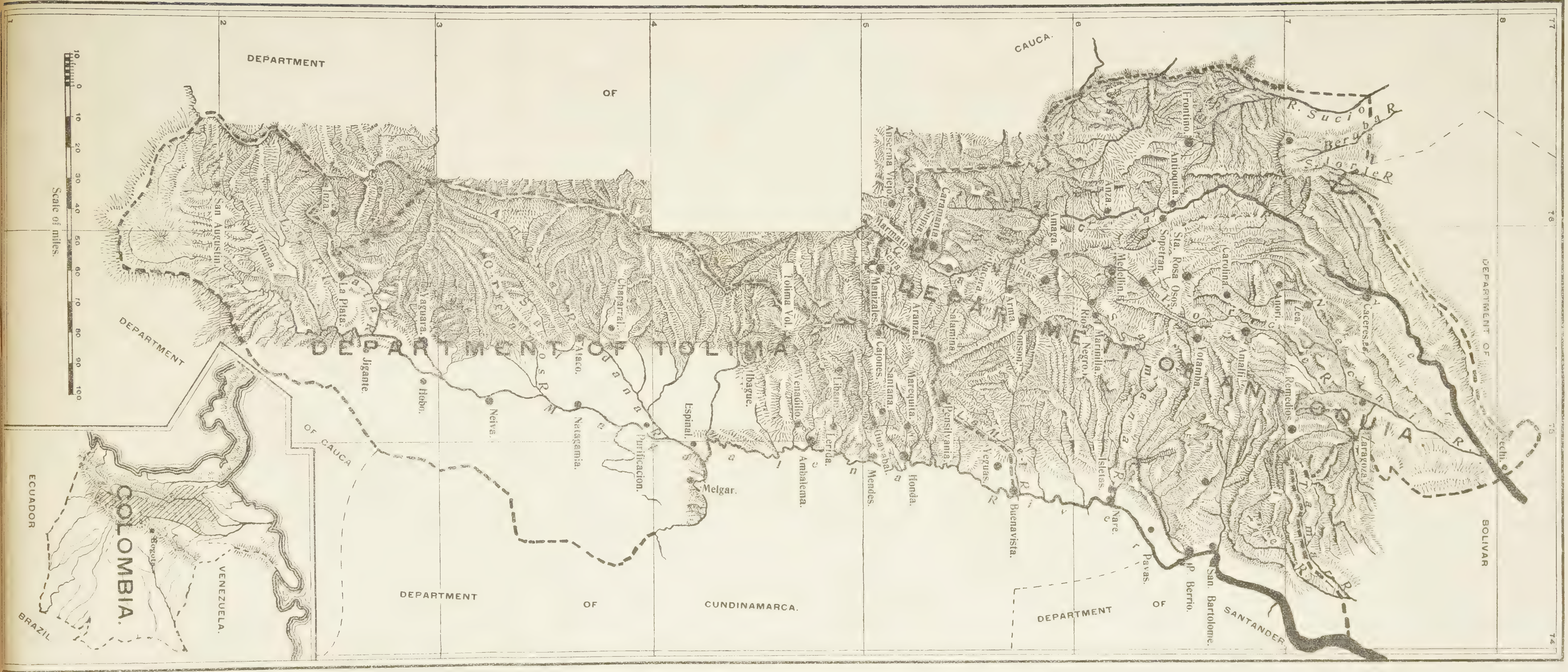
Modern Gold Mining in the Darien: Notes on the Reopening of the Espiritu Santo Mine at Cana. Ernest R. Wokes. *A paper read at the New York Meeting of the American Institute of Mining Engineers, February, 1899.*

MAP OF THE MINING REGIONS OF THE DEPARTMENTS OF ANTIOQUIA AND TOLIMA.

The accompanying map has been compiled from the standard atlases, the map published by the Bureau of American Republics, and numerous others. The topography in great part has been derived from the numerous detailed maps of various localities in Colombia, given in the work of Reclus before quoted, and from the large official map of the former State of Cauca. It is designed only to show the position of the mining towns referred to in this work, their relations to the important cities of the Republic, and the topography of the intervening territory. A few of the more important mining towns, not included in the scope of this work, have also been entered. It has been thought best not to burden the map with many of the smaller places, especially as in the majority of cases the locations given them by the different maps do not agree. During the compilation it was discovered that hardly any two maps of Colombia are consistent with each other. Differences of fifteen or twenty miles in the location of towns are common, and much greater differences are not unusual. On one map, Ibagué, the capital city of Tolima, is entered twice under slightly different spellings. These discrepancies, in addition to the duplication of names common in Latin-American countries, are due to two causes. For many years maps were based upon certain determinations of Humboldt, which were in error and shifted the section of the Andes between Bogota and Cuzco too far to the west. The errors have been corrected from time to time as other surveys have been made along the line of the coast and for railways. Thus it comes that maps made from data collected at different times differ. The other reason for discrepancies in the location of the towns is that some of the towns (*e. g.*, Remedios, see page 132) have been moved from time to time, owing to failure of mines, or the mortality due to an unhealthful climate.

FIEL

REPUBLIC OF COLOMBIA.



Map of the Mining Regions of the Departments of Antioquia and Tolima in the Republic of Colombia.

FIELD COLUMBIAN MUSEUM
PUBLICATION 34.
GEOLOGICAL SERIES. VOL. I, NO. 4.

THE MYLAGAULIDÆ:

AN EXTINCT FAMILY OF SCIUROMORPH RODENTS

BY

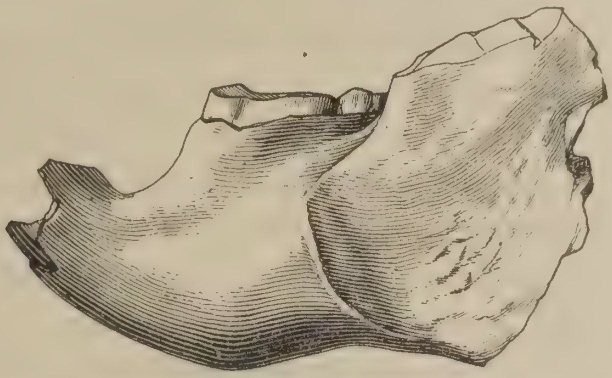
ELMER S. RIGGS, A.M.,
ASSISTANT CURATOR, DEPARTMENT OF GEOLOGY.

OLIVER CUMMINGS FARRINGTON, PH.D.,
CURATOR, DEPARTMENT OF GEOLOGY.

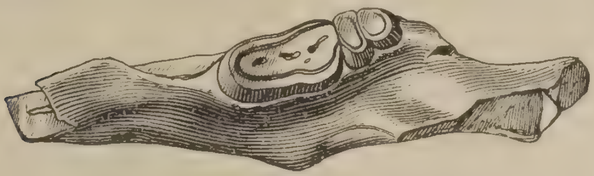
CHICAGO, U. S. A.
March, 1899.

THE MYLAGAULIDÆ; AN EXTINCT FAMILY OF SCIUROMORPH RODENTS.

The genus *Mylagaulus**, Cope, was originally based upon a single lower premolar tooth, but later it was supported by the description of a fairly complete mandible.† From this material two species were determined, *M. Monodon* and *M. sesquipedalis.* Later the family name, *Mylagaulidæ,* was proposed for these forms. To this group it is now proposed to add the two genera described below.



Lateral view of mandible of *Mesogaulus ballensis* × $\frac{5}{3}$.



Dentition of same as seen from above × $\frac{5}{3}$.

Mesogaulus ballensis, *gen. et sp. nov.*

A rodent mandible from the Deep River escarpments near White Sulphur Springs, Montana, and now in the Museum collection, shows interesting characters hitherto undescribed. As suggested by Professor Scott, its nearest affinities are with *Mylagaulus*, Cope, though it is a more primitive form and evidently stands in an ancestral relation to that group. The name *Mesogaulus ballensis* is proposed for it in honor of Mr. S. H. Ball, the collector. The characters distinguishing this genus from *Mylagaulus* are: First molar elongate antero-posteriorly with enamel slightly inflected externally; the third molar rather stronger than the second and rotund in outline. The type specimen was found in the alluvium at the base of an escarpment, so that its horizon cannot be exactly determined. However, it certainly belongs to the upper beds.‡

---

*Bulletin of the U. S. Geological and Geographical Survey, vol. iv., No. 2, May, 1878.

†American Naturalist, Jan. 1883.

‡The Mammalia of the Deep River Beds, Am. Phil. Soc., Oct. 1893.

The specimen consists of a single mandible from which the angle, condyle, part of the coronoid process and the tip of the incisor have been lost. The remainder is in good preservation and shows a perfect molar dentition. The teeth are deeply set in the alveolus and their well-worn crowns indicate an animal fully adult. The molars are ranged in a line parallel to the plane of the symphysis, but the axes of the teeth themselves are inclined well inward at the crowns. As in *Mylagaulus*, the angle of the mandible is within the plane of the incisive alveolus, but the condyle would fall somewhat without it. The coronoid process is strong at the base and is directed outward, leaving a broad fossa between its mesial surface and the posterior molars. At the hinder margin of this fossa the dental foramen opens. Almost continuous with the anterior margin of the coronoid process, arising just below the posterior third of the premolar alveolus and extending downward toward the angle, is a strong masseteric ridge. The symphysis extends far back beneath the premolar alveolus where its termination forms a prominent angle in the inferior outline of the mandible. The ramus is concave on the mesial surface throughout, and posteriorly bears evidence of a deep fossa. The incisor is covered anteriorly with a thin orange-colored enamel. At the alveolus, where it is broken, the section is roughly sub-triangular. The anterior surface meets the median one in a sharp angle; with the lateral surface it forms a rounded one; while posteriorly the faces converge to form a single rounded surface. The premolar, as before mentioned, has its crown much elongated antero-posteriorly and the enamel slightly inflected on the lateral margin. A series of three enamel fossettes are arranged in the median line of the crown, with a trace of a fourth lying lateral to them. The anterior surface is comparatively narrow, the crown reaching its greatest width opposite the third fossette, while opposite the middle one occurs the external enamel inflection. The second molar is a small tooth, compressed antero-posteriorly, and like the third, entirely devoid of fossæ or enamel inflections. In both, the enamel is absent from the mesial surface and in the first it is noticeably thinner. All are encased in thick sheaths of cement. The last molar is grooved on the mesial surface throughout its length, indicating the not very remote coalescing of roots. The other molars I have not examined below the alveolus. A possible trace of a fourth alveolus remains, but the space between the third molar and the dental foramen is so reduced that a fourth tooth could not have developed in this individual.

MEASUREMENTS.	M.
Length from posterior incisive alveolus to posterior molar surface	.023
Length of inferior molar series	.013
Length of diastema	.010
Antero-posterior diameter of premolar	.009
Greatest lateral breadth of premolar	.0042
Greatest lateral breadth of last molar	.0035
Depth of mandible at anterior molar alveolus	.017

Protogaulus hippodus gen. nov. (sp. Cope.)

In view of the later described relationship of *Meniscomys hippodus** to the *mylagaulid* phylum, as well as its differences from other members of the genus, it seems desirable for the sake of natural grouping to transfer the species to the *Mylagaulidæ.* Upon these grounds it is proposed to create for it a new genus, retaining the specific name. The generic characters thus distinguishing *Protogaulus* from *Meniscomys* are: "Superior molars short-rooted with external face plane; inferior molar with a prominent median transverse crest;"† premolar much larger than molars and having the crescents separated by a deep external fissure; inferior incisor with a wide groove on its external face.

MEASUREMENTS.†	M.
Length of superior molar series	.008
Length from base of first superior molar to base of incisor	.0065
Width between bases of first molars	.002
Length of first inferior molar	.0033
Depth of ramus at second molar	.0050

RELATIONSHIP: The relations of *Mylagaulus* were for some time left in doubt, but eventually Professor Cope proposed for these forms the family *Mylagaulidæ.* As pointed out by him, the marked development of the lower premolar and the characters of its crown present striking similarities to the dentition of certain species of *Hystrix*, especially *H. refossa.* But the complete absence of roots, even in the more primitive form, *Mesogaulus,* together with the dissimilar origin of the angular portion of the mandible, render the suggested relationship improbable. All of these characters are essentially *sciuromorph* and to that group the *Mylagaulidæ* certainly belong.

The presence of but three molar teeth and the complete isolation of the enamel fossettes were offered as grounds for the erection of the family *Mylagaulidæ.* If these characters were possessed by no other forms they might be regarded as of more than generic importance, but in point of fact, the dental formula is the same as that of *Eucastor* Leidy* and the later described *Sigmogomphius* Merriam,† both of which have true *castoroid* affinities. As to the second feature, the isolated enamel lacunæ are independently developed in several forms and are doubtless dependent upon the amount of wear to which the tooth is subjected. Therefore this group has not been generally recognized by later writers, and the genus has been provisionally included under the *Castoridæ*.

---

*Proceedings American Philosophical Society, 1878 (-79), p. 67.

†Cope's Tertiary Vertebrata, p. 829.

Nevertheless the *Mylagaulidæ* appear to be a unique, and, until now, isolated, form. The one prominent feature is the unusual development of the premolar to the exclusion of the posterior-lying teeth. Associated with this is the great strength and shortness of the mandible, the prominence and anterior position of the masseteric ridge and the depth of the ramus from alveolus to angle. These tell an unmistakable story: Unusual capacity for crushing or grinding and the attendant specialization of the premolar to perform the function laid upon it. Just as in the *Carnivora*, the lower first molar, lying immediately anterior to the insertion of the masseter muscles, has developed into the principal shearing tooth; so in these forms, the last premolar, standing in the same relation, has fitted itself for a crushing implement which, in *M. Monodon*, has reached the highest degree of specialization known to *Rodentia*. It would be most interesting to know the food habits of these unique animals. Such a *machoire* might well have fitted them for nut-cracking or the crushing of hard-shelled seeds; but the abraded crowns of all the molars, together with their hyposodont character of growth, makes it probable that the great tooth with its enamel pits was used largely as a grinding surface.

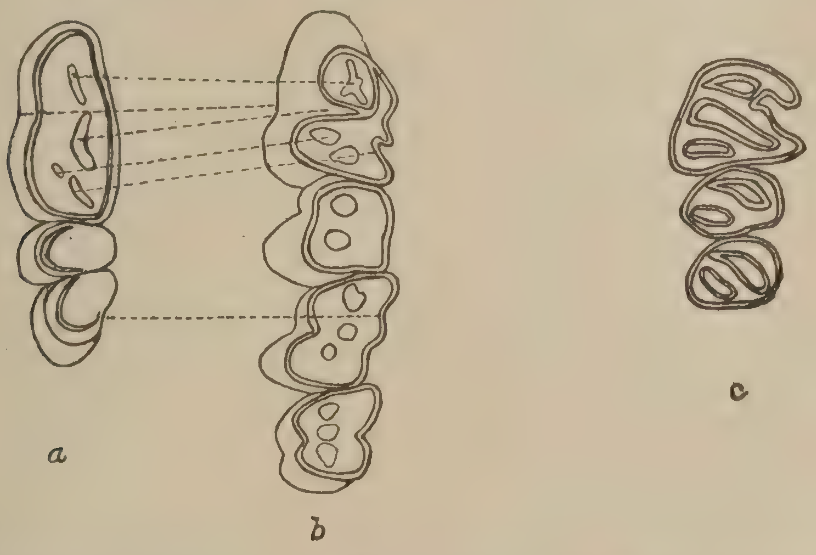
PHYLOGENY OF THE MYLAGAULIDÆ.

Upon the problem of phylogeny the limited material thus far known throws comparative little light. An ancestor of *Mesogaulus* would be expected to have a less strongly developed premolar with at least one lateral enamel inflection, to show traces of a third lower molar, and perhaps retain further evidences of molar roots. These conditions are largely fulfilled in the proposed genus *Protogaulus hippodus*. In this form the mandible has the premolar considerably enlarged, though the crown is little elongate antero-posteriorly. The third molar is retained, but is somewhat smaller than the second, and short roots are present throughout. Cope describes the mandibular dentition as follows:* “The crowns of the inferior molars, in the unworn condition, terminate in two crescents; that is, in elevated, anterior, external and posterior borders, with a transverse ridge equally dividing the space thus marked out and joining the notch in the external crest. This pattern resembles somewhat that of *Anchitherium*. The first inferior molar (premolar) differs from the others in its superior size and its having the crescents more widely separated by a deeper external emargination. On attrition the spaces bounded by the enamel crests are enclosed by the junction of the extremities of these crests on the inner side of the crown. Further attrition results in three lakes within the crown and one notch of the external border and two notches of the internal border. The anterior molar has two lakes in its posterior area and one large one in its anterior area. In old teeth there are successively one and no lakes left to interrupt the dentine. The inferior incisor has a wide shallow groove or concavity on its external face.”

---

*American Naturalist, July, 1881, p. 586.

†Bulletin of the Department of Geology, Univ. of California, vol. 1, No. 13.



(*a*) Lower dentition of *Mesogaulus* × 2. (*b*) The same of *Protogaulus* (*Meniscomys*, Cope) × 4. (*c*) Upper dentition of *Hystrix refassa* × 2.

From this the affinities with *Mesogaulus* at once appear. In that genus the lateral emargination of the premolar has almost disappeared, and the cleft is represented by the deeper middle fossette. The large anterior lake described in *Protogaulus* is replaced by a smaller one in the later form; the deep postero-internal cleft is traceable in the elongate third fossa, which is barely separated from the enamel border. A mere trace of a fourth fossette lying lateral to, and between the second and third, doubtless represents the posterior one in the ancestral form. The true molars have lost their important characteristics in the process of reduction, but even in the earlier form the first molar shows the antero-posterior compression so noticeable in *Mesogaulus*, while in that form the second molar retains something of the diagonal elongation seen in the other, and also a trace of its median internal flexure.

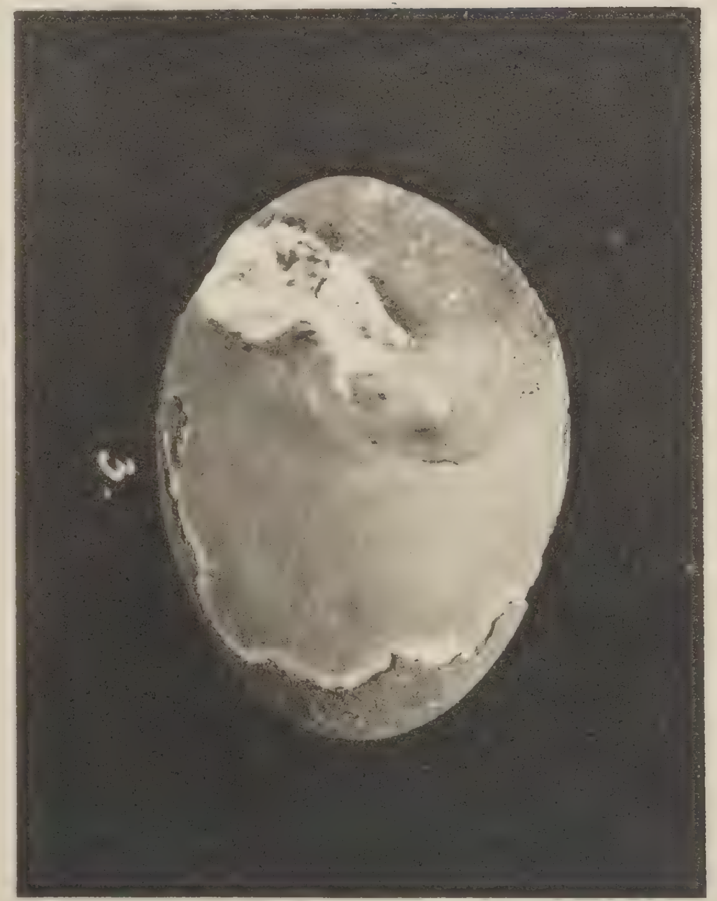
---

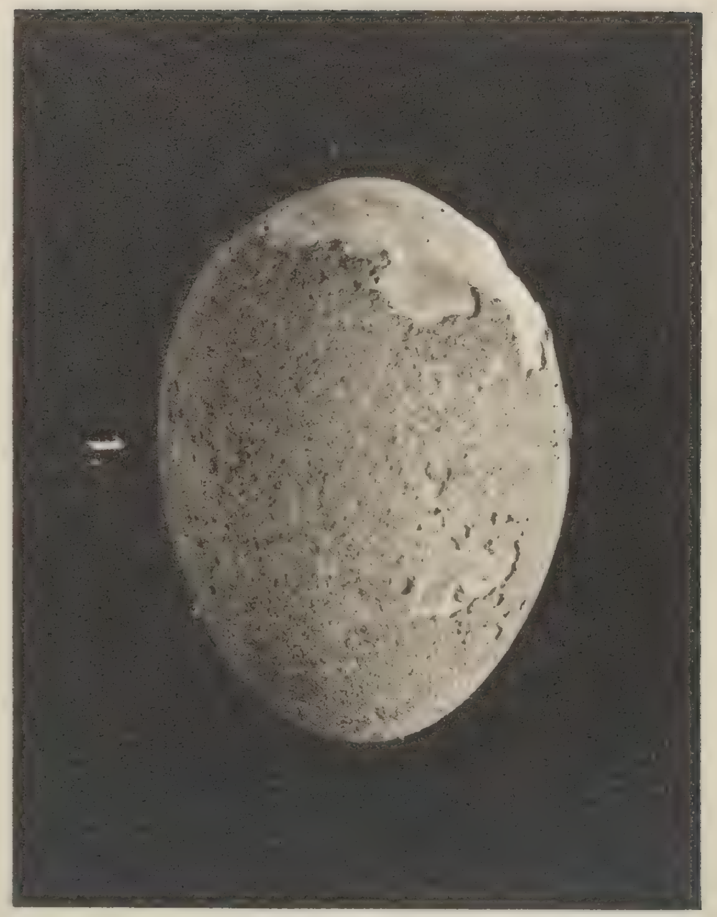
*Cope's Tertiary Vertebra, p. 828.

The following table will be of service in showing the distribution, both in time and locality, of the extinct *sciuromorph* rodents. It is based upon Zittel's classification, except in instances where later discoveries have thrown additional light upon the subject:

DISTRIBUTION OF SCIUROMORPH RODENTS IN NORTH AMERICA.

	Oligocene.	MIOCENE.			Pliocene.	Pleistocene.
	White River.	John Day.	Deep River.	Nebraska Beds.	Diluvium.	Cave Deposits.
Geomyidæ:						
Gymnoptychus montanus	×					
“ *trilophus*	×					
Heliscomys vetus.	×					
Pleurolicus leptophrys		×				
Entoptychus crassiramis				×		
“ *planifrous*				×		
Castoridæ:						
Steneofiber nebrascensis	×					
“ *peninsulatus*	×					
“ *pansus*	×					
“ *gradatus*		×				
“ *montanus*			×			
Eucastor tortus				×		
Castor fiber					×	×
“ *pelicedens*						×
“ *rosinæ*						×
Sciuridæ:						
Arctomys vetus				×		
“ *monax*						×
“ *fossilis*						×
Sciurus relictis	×					
“ *vortmani*		×				
“ *calycinus*						×
“ *panolius*						×
Tamius lavideus						×
Meniscomys liolophus		×				
“ *cavatus*		×				
“ *niteus*		×				
Mylagaulidæ:						
Protogaulus hippodus		×				
Mesogaulus ballensis			×			
Mylagaulus sesquipedalis				×		
“ *monodon*				×		





FOSSIL EGG IN ND STRUCTURE.

Field Columbian Museum
Publication 35.
Geological Series. Vol. I, No. 5.

A FOSSIL EGG FROM SOUTH DAKOTA

BY

Oliver Cummings Farrington, Ph.D.,
Curator, Department of Geology.

Chicago, U. S. A.
April, 1899.

A FOSSIL EGG FROM SOUTH DAKOTA.

The specimen (Museum No. P 5734) described in this paper is believed by the author to be a petrified egg of an Anatine bird of Early Miocene age. If this supposition be correct, the specimen seems to warrant description both as an interesting case of petrifaction and as indicating the presence of aquatic birds about the waters of the great lake which is generally considered to have occupied in early Tertiary times the region where the specimen was found. The original finder of the specimen was Mr. Kelly Robinson of Dakota City, South Dakota. He stated to the writer that while riding one day in the summer of 1896 in the region of the Bad Lands he saw this object lying at the foot of "a bad land"* and in a shallow gully. It had apparently washed there from "the bad land" above. Mr. Robinson picked it up and concluding, on examination, that it was a petrified egg, took it home for a curiosity. From him it was obtained by the writer for the Museum in the winter of 1897. The specimen is not quite completely ovoid in form since from one end a portion has been broken away. Mr. Robinson stated that this portion was missing when he found the specimen. The form of the specimen is fully indicated by Figs. 1, 2 and 3, Pl. XX, where are shown photographs of it in three different positions. As may be seen from these figures, the resemblance of the specimen both in form and structure to an egg is very striking. Covering most of the exterior is a thin, black layer .017 of an inch in thickness which closely resembles in thickness and appearance an egg shell. Within this and constituting the major portion of the specimen, is a mass of pale gray translucent chalcedony, corresponding in appearance and amount to the white of an egg. Near one side but enveloped in the preceding is a white, opaque, ovoid mass .66 of an inch in diameter which can be easily seen to correspond in size and position to the yolk. If the specimen be not a petrified egg, therefore, it is as perfect an imitation of one in external appearance as can be conceived of.

In order to determine the existence of any special characters in the mineral matter of the specimen this was studied somewhat in detail. The portion which may sufficiently be designated as the shell, was found to be translucent chalcedony similar to that of the main mass, or what may be called the white, and for the most part confluent with it. It is, however, dark brown to black in color. On heating to redness this color disappeared, indicating organic matter to be the coloring ingredient. In one or two spots the shell was not homogeneous throughout, a thin white layer separating it from the main portion. This, on testing, proved to be carbonate of lime, indicating that here some of the original shell had not been replaced by the petrifying siliceous solutions. No definite structure or markings could be distinguished on the shell. While generally smooth in outline, under a lens it is seen to be rough and porous, owing doubtless to the action of the infiltrating waters. The original markings, if any, must have been destroyed by such an action.

---

* In modern Western parlance "a bad land" is any knoll or slope barren of vegetation.

The portion designated as representing the white of the egg is, as has been said, made up of pale gray translucent chalcedony. It is homogeneous throughout except for occasional black blotches, some of which resemble in arrangement those of moss agate, while others show concentric distribution. It could not be determined without sacrificing too much of the specimen, whether these were formed by organic matter or by mineral matter such as oxides of iron or manganese. The chalcedony resembles in its characters that of the veins of that mineral which traverse the region and which have been described by other authors.* On heating fragments of the chalcedony it turns white and opaque but yields only a trace of water. It is infusible and has a hardness of 7.

It is to the portion designated as the yolk that the greatest interest attaches. This has already been described as a white opaque ovoid mass .66 inch in diameter, enveloped in the chalcedony. On close examination this white mass can be seen to be made up of two portions of about equal size which have different structure. That nearer the center of the egg is made up of little spherules and thin curving plates. The spherules average about 1 mm. in diameter and have a distinct concentric structure, coats of alternately opaque white and translucent dark matter being deposited around each center. So far as can be judged from the color of these coats they are opal and chalcedony, respectively, but color is not, of course, in such a case, an accurate criterion. The thin curving plates are similarly made up of white and dark layers.

The other portion of the "yolk" is composed of a yellowish-white opalescent substance quite homogeneous except for occasional darker spherules, which show a concentric structure similar to those of the other portion. The opalescent substance appears both in its chemical and optical characters to be true opal. It is considerably cracked. It is infusible B. B., but has a hardness less than 7. On heating in the closed tube it gives off a little water, turns black in spots and emits a distinct odor of burning nitrogeneous matter. This I conjecture to come from some of the original organic matter of the egg, which has not ~~as yet~~ been replaced by siliceous matter. As such an occurrence had not come within my observation before, I thought it well to test some other petrified substance to learn if it contained any organic residue. Accordingly, fragments of the well-known petrified wood from Sonoma County, California, were put to a similar test, and somewhat to my surprise an odor of smoking wood was distinctly given off. It therefore seems probable that in many petrified substances some of the original organic matter may remain imprisoned.

---

*J. B. Hatcher, Am. Naturalist, March, 1893, p. 218. E. C. Case, Am. Geologist, April, 1895, p. 248.

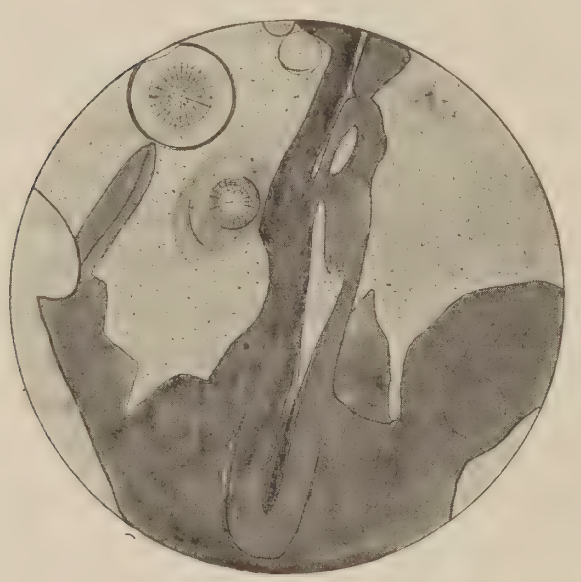
In order to determine whether any remains of cell structure were to be observed, a fragment from the portion where the "white" and "yolk"—in other words, the chalcedony and opal—join, and which showed as well a spherule of chalcedony, was ground thin for microscopic examination. As shown by the drawings, Figs. 1 and 2, nothing like cell structure is to be seen in the section. The chalcedonic portion shows several spherules, but these do not differ in character from those usual to chalcedony. In the portion made up of opal an elongated cavity is to be seen which suggests in form a compressed air bubble. This is lined with two successive layers which may follow some membranous structure, but of this there is no certainty. The portion of the section made up of opal, when viewed in ordinary light, is of a yellowish-brown color, and shows no other structure than that mentioned. In polarized light it becomes wholly dark, showing its amorphous and singly refracting character. The portion made up of chalcedony is colorless in ordinary light except for the spherules previously mentioned. These are bounded by a thin, yellow ring, within which is a transparent area, and within this, making up the central portion, is another yellow mass, having a distinctly radiated fibrous structure. The general appearance of the spherules in ordinary light is thus very much like that of those of the siliceous oölite of Pennsylvania, which has been described by Barbour and Torrey* and E. O. Hovey.†

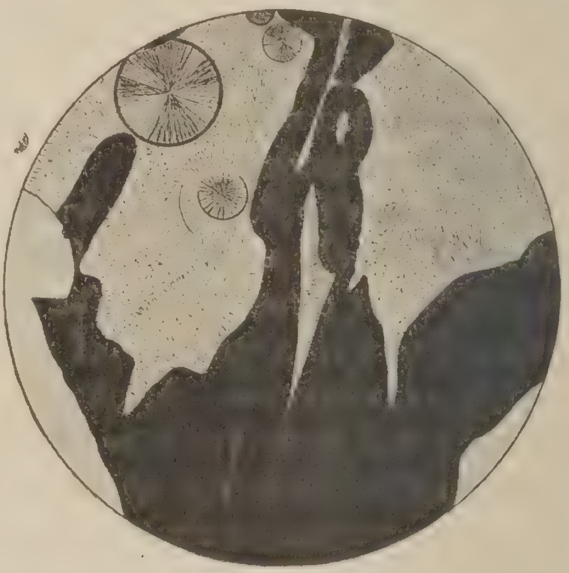
---

* Am. Jour. Sci., 3d Ser., Vol. XL, p. 246.

† Bull. Geol. Soc. of America, Vol. V, p. 627.

In polarized light the yellow outer ring of the spherules remains dark during a revolution, indicating it to be opal. The interior portion assumes an appearance like that of granular quartz. This is similar to that described by Hovey as characterizing the interior of some of the spherules of the Pennsylvania oolite. The spherulitic interference cross is, however, clearly to be seen, and the optical character is negative. Hence the method of formation can not be regarded as similar to that proposed by Hovey for the siliceous oolite, but is probably a simple spherulitic structure, in accordance with which any foreign matter, such as the opal, was arranged. The main portion of the chalcedony shows a typical radially fibrous structure.





[DRAWN WITH CAMERA LUCIDA.]

FIG. 1. Section from "yolk" in ordinary light. Dark portion opal; light portion, including spherules, chalcedony.

X22.

FIG. 2. Same in polarized light. The opal becomes black; the chalcedony shows a fibrous structure and the spherules interference crosses.

X22.

A section of chalcedony from the veins of the region, studied for comparison, showed a similar strongly marked fibrous character and tendency to radial arrangement.

The specific gravity of the specimen as a whole was found to be 2.594, or about that of chalcedony.

It is of course desirable, if possible, to obtain an explanation of the way in which so unique a case of petrifaction could occur, if petrifaction it be. I have been unable to find any account of a similar occurrence as having been noted before. The fossil Chelonian eggs of Tertiary age from Auvergne, France, are simply shells filled with hardened mud. The fossil eggs of the New Zealand birds are likewise only shells, which have been preserved by reason of their thickness. Neither of these occurrences are, therefore, cases of true petrifaction. At first thought, an egg of the sort here described may seem too perishable for preservation by a process of true petrifaction. It is difficult to understand how, in such a mass as an egg, petrifying liquids could pass to and fro, removing particles of organic matter and replacing them by particles of silica, in the way that it is generally understood that petrifactions usually take place. On further consideration, however, the natural petrifaction of an egg need not seem to be an impossible phenomenon. If covered as soon as deposited, by mud or earth, as it is likely to have been in this region, its substance might endure for months or years. Or, the process of petrifaction might have begun at once, since the present chalcedony veins of the region show that circulating siliceous waters are abundant there.

Given conditions of this sort, I believe that petrifaction could have gone on by a process of endosmose and exosmose similar to that believed by M. Forster Heddle* to produce the formation of agates. As the cases seem so similar in their conditions, his theory may be quoted in full: "We have now a cavity slightly lined with chalcedonic matter, containing, within, water more or less pure, while without (that is, outside the now double skin, delessite and first layer), we have a strong solution of colloidal silica constantly supplied. Endosmose and exosmose are set up with resistless force. The *strong* solution finds its way through the two or any number of increasing skins; the *weak* water is forced out through the point of infiltration, and so in its passage out thins all the successively deposited layers at that place. By the continuous flow of colloidal silica (held in solution by liquid) through the already coagulated or deposited layers, continuous coagulation of the silica in the yet hollow agate, and continuous extrusion of the residual water, we have the ultimate filling up of the cavity, and a solid agate formed." The parallelism of conditions in the two cases is so apparent as to need no emphasis. The shell of the egg and its lining membrane furnish the "skin," the albuminous or watery substance within the egg the weak solution, and the circulating siliceous waters known to abound in the region the strong solution of colloidal silica. Or the positions of the latter may have been reversed, the thicker liquid having been within and the thinner without. In either case a transference would take place. While I cannot say that Professor Heddle's theory, that agates have been formed in this way, is altogether the adopted one, the stages of the process as he describes them at least seem logical and reasonable, and may well have brought about petrifaction in the case of an egg. Of course it is not held as proved that, in the specimen under consideration, those portions which I have designated as white and yolk have been preserved in their original structure and proportions. While this may be the case, it is again quite as likely that the portion which I have designated as the yolk represents the shrunken residue of the egg substance as a whole. Its appearance, indeed, rather indicates this, since the curved plates that have been described resemble shrunken membranes. The remainder of the interior may then have been filled simply with water at the time petrifaction set in.

---

* Nature, Vol. XXIX, p. 419.

It is more difficult to explain the fact that most of the "yolk" is composed of opal while the rest of the interior is made up of chalcedony. The difference is, however, not essentially greater than that often found to exist in different layers of agates.

For establishing any conclusions as to the nature of the parent of the egg, no other data are available than its form. For a knowledge of what this indicated I referred to Mr. Wm. A. Bryan of the Museum, who has very kindly furnished the following report: "The form of the specimen suggested to me on the first examination that it was that of an egg of one of the Anatidæ or Duck family. Further study confirmed this conclusion, the similarity in form to that of eggs of Anatine birds being marked and such as to distinguish it from the eggs of birds of other families. Measurements of the fossil egg, too, showed it to have the same proportions as those of members of the Anatidæ, while they differed to a marked degree from those of other families. These similarities and differences are illustrated in the eggs shown in Pl. XXI. The eggs there shown were selected to represent as nearly as possible types having the general oölogical characters of the different families of birds whose eggs might resemble the fossil form, or whose habits would lead them to deposit eggs under conditions favorable for petrifaction. To complete the form of the fossil egg for this purpose, the outline on the broken end was filled out with plaster. By this method the form of the egg was reproduced, any error being probably within $\frac{1}{100}$ of an inch. The measurement of length was therefore made on this completed egg."

"The following table shows the species of eggs chosen and their measurements:"

No.	Order.	Family.	Species.	Common Name.	Measurements. (Eng. inches.)
1	....	....	....	Fossil Egg....	2.03 × 1.49
2	Anseres	Anatidæ	Anas fulvigula	Florida Duck.	2.05 × 1.52
3	Longipennis..	Laridæ.......	Sterna fuliginosa........	Sooty Tern....	1.84 × 1.28
4	Gallinæ.......	Tetraonidæ...	Tympanuchus americanus.	Prairie Hen ..	1.72 × 1.28
5	Limicolæ.....	Charadiidæ...	Charadrius dominicus.....	American Golden Plover	1.86 × 1.40
6	Herodiones...	Ardeidæ......	Ardea cærulea	Little Blue Heron.....	1.73 × 1.30
7	Pygopodes....	Podicipidæ...	Podilymbus podiceps....	Pied - billed Grebe.....	1.71 × 1.19
8	Steganopodes.	Phalacrocoracidæ........	Phalacrocorax p. robustus...	Violet Green Cormorant.	2.52 × 1.51

It will be seen that in form and proportional measurements the fossil egg resembles most closely that taken as the type of the Anatidæ. The probability of its parent belonging to that family is also increased when one considers the nature of the formation in which the egg was found. This is of lacustrine origin, and birds of this family are well known to frequent the waters of lakes. Unfortunately, from the manner in which the egg was found, it cannot be stated positively that it came from the beds immediately adjacent. These are of White River age, but as the specimen was not found *in situ* it may of course have come from later and higher beds, or, as has been suggested, be even an egg of a comparatively modern bird. Yet the probabilities are strongly in favor of the supposition that the specimen was, until just before it was found, imbedded in the formation immediately adjacent, and was brought to light by erosion, just as bones of extinct vertebrates are continually being exposed in the same region at the present time. If these suppositions are correct, the specimen affords evidence of the existence of birds of the order Anatidæ in Early Miocene times.

The only other mention of the finding of bird remains in rocks of this period, in this country, of which I am aware, is that of two species of birds from the Amyzon shales of Nevada. These remains consist of scattered bones and feathers, and represent birds one species of which has been described by J. A. Allen* as a passerine bird of the family Fringillidæ, the other by E. D. Cope† as a species of the order Grallæ and tribe Limicolæ.

In conclusion, the hope may be expressed that if any specimens of similar character are known they will be fully described, so that more evidence may be at hand to clear up the difficulties encountered in the study of this one. I have reports of the finding of at least two other petrified eggs at different times in the same region, but have been quite unable to verify the reports or see the specimens. A systematic study of the forms of eggs seems also desirable, so that in the future definite conclusions may be drawn regarding the order or family to which a parent belonged when an egg is the only relic of the parent to be obtained.

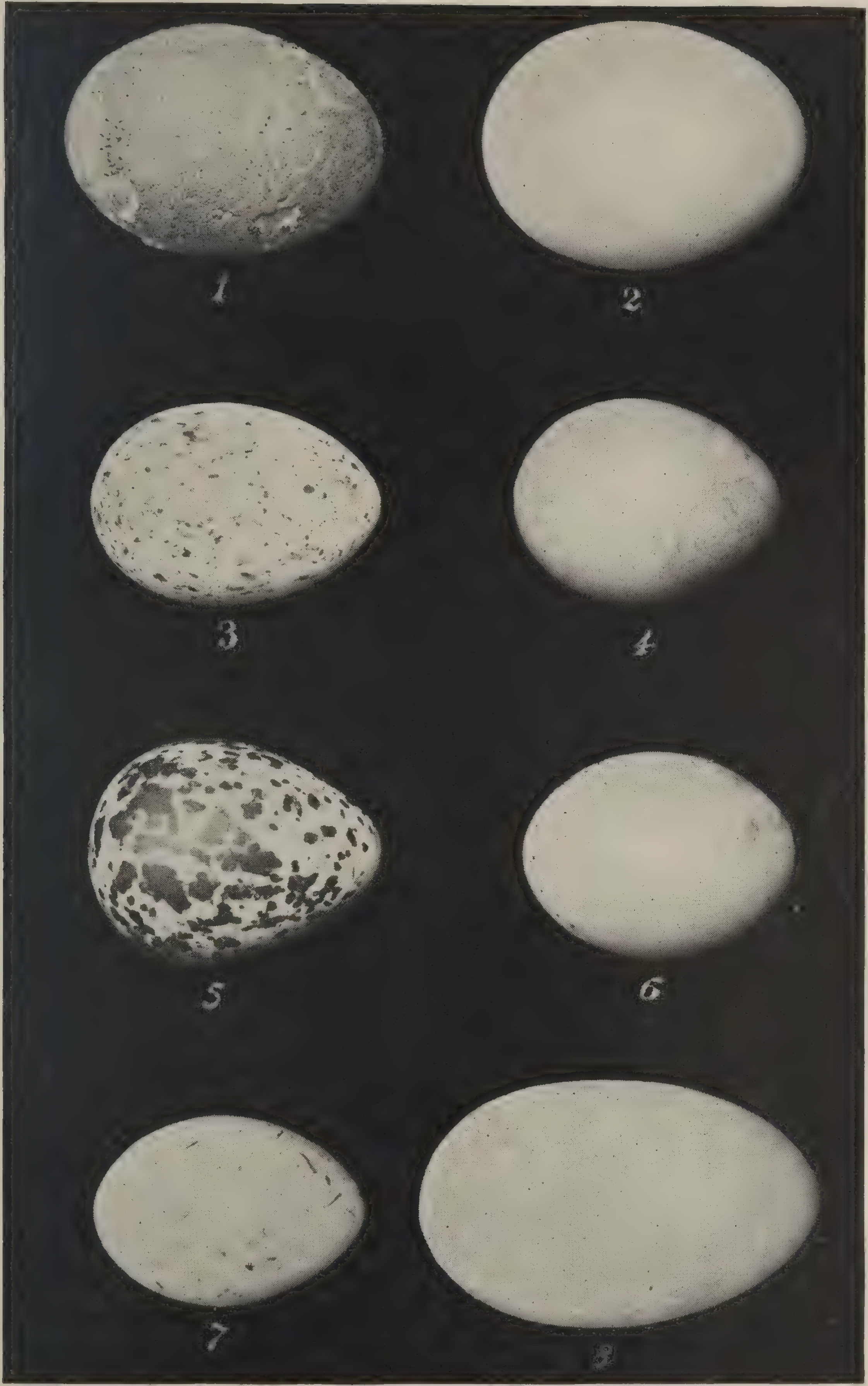
---

*Bull. U. S. Geol. Surv. Terrs., IV, 1878, p. 443, Pl. I.

†Rept. U. S. Geol. Surv. Terrs., Vol. III, Book I, p. 754, Pl. LIX.

PL. XXI. FOSSIL EGG AND EGGS RESEMBLING IT IN FORM OR PROBABLE HABITAT OF PARENT.

Fig. 1. Fossil Egg.
Fig. 2. Egg of *Anas fulvigula.* Florida Duck.
Fig. 3. Egg of *Sterna fuliginosa.* Sooty Tern.
Fig. 4. Egg of *Tympanuchus americanus.* Prairie Hen.
Fig. 5. Egg of *Charadrius dominicus.* American Golden Plover.
Fig. 6. Egg of *Ardea cærulea.* Little Blue Heron.
Fig. 7. Egg of *Podilymbus podiceps.* Pied-billed Grebe.
Fig. 8. Egg of *Phalacrocorax p. robustus.* Violet Green Cormorant.



Fossil Egg and Eggs Resembling It in Form and Probable Habitat of Parent.

LIBRARY
OF THE
UNIVERSITY of ILLINOIS.

FIELD COLUMBIAN MUSEUM
PUBLICATION 36.
GEOLOGICAL SERIES. VOL. I, NO. 6.

CONTRIBUTIONS TO THE PALEONTOLOGY OF THE UPPER CRETACEOUS SERIES

BY

WILLIAM NEWTON LOGAN, A.M.

OLIVER CUMMINGS FARRINGTON, PH.D.
Curator, Department of Geology.

CHICAGO, U. S. A.
April, 1899.

CONTENTS.

	Page.
Introductory Note,	205
The Genus Scaphites	207
Scaphites warreni,	210
Prionotropis woolgari,	211
The Genus Ostrea,	213
Ostrea beloiti,	214
Fasciolaria,	214
Fusus,	215
Astrocœnia conica,	215
Pseudo-perna wilsoni,	215

ILLUSTRATIONS.

Plate.	Opposite page.
XXII.	209
XXIII.	210
XXIV.	211
XXV.	214
XXVI.	215

INTRODUCTORY NOTE.

The specimens described in this paper were collected by the writer at different times while studying the geological formations of Kansas. The Ft. Pierre fossils were collected from the deposits bearing that name in the extreme northwestern part of the State. The Benton fossils were obtained from outcrops of that formation in the central part of the State, in Osborne, Lincoln and Mitchell Counties. The Niobrara species were collected from outcrops on the Smoky Hill river in Ellis County, and from outcrops on the White Rock in Jewell County.

Some of the Benton forms, particularly the gastropods, were taken from calcareous nodules which were so thoroughly indurated that the shell could not be obtained in a form complete enough to warrant specific determinations. Nevertheless, they are figured and the best description possible from the material is given. The remaining specimens are well preserved.

A comparison of some of the species of the same genus led the author to a study of the distribution, ontogeny, and phylogeny of some of the genera. The results of this study are included in the present paper.

The specimens treated of in this paper are now in the paleontological collection of the Field Columbian Museum.

THE GENUS SCAPHITES.

Distribution. The genus Scaphites belongs to the family Stephanoceratidæ of the order Ammonoidea. The genus includes about forty known species. Its geological range is confined to the Upper Cretaceous Series, but its distribution is widespread, as it is known to have been an inhabitant of at least four continents. The species were no doubt marine littoral organisms.

The history of the genus forms an interesting record. The earliest known species occurs in the Gault of Europe which seems to form a transition stage from the Lower to the Upper Cretaceous, for it is classed by some authors with the former and by others with the latter series. In this earliest known horizon of the genus there are few species, and individuals are not abundant.

In the formation overlying the Gault, the Cenomian, the primitive species, *Scaphites æqualis* Sowerby, reaches the acme of its abundance. Up to this time, however, few, if any, structural variations have been introduced. But during later Cenomian time dispersion began and the primitive species made its appearance in the Cretaceous seas of France and Switzerland. With the migration came new environments which resulted in a differentiation of organic structure, and the consequent production of new species. All of the new species, however, are closely allied to *S. æqualis.*

It is, of course, questionable whether environment is the sole cause of variability. But it is very highly probable that in this case, at least, the change of environment was one of the prime factors in the production of the new species. For it is not improbable that under new conditions bathmism could more readily assert itself. That it did assert itself rapidly is shown by the production, in a short period, geologically speaking, of nearly fifteen species. From this it must at least be inferred that the change in environment gave an impetus to the growth force. It becomes more obvious in the light of the fact that in the center of dispersion but three or possibly four species are recorded for the entire geological range of the genus. Furthermore it is not certain that two of these species did not migrate to the center of dispersion from the Eastern colonies.

During middle Upper Cretaceous times the genus continued its eastward migration. From India two or three of the primitive types are reported. From the Pacific coast of North America one species which is very closely allied to the early forms has been discovered. During middle Upper Cretaceous times came the introduction of the waters of the great North American epicontinental sea, and with the waters of this sea came in some of the primitive species from the Western or Eastern waters. And here as in the epicontinental sea of Europe conditions favorable to development were found. Bathmism here also found a strong ally in environment, and the result was the production of thirteen or fourteen new species. But differentiation of structure was of a greater degree. The development was more accelerated and the changes more marked. The individual grew to much larger size; nodes were developed where ribs only had existed; the sutures became more complex and the form more globular.

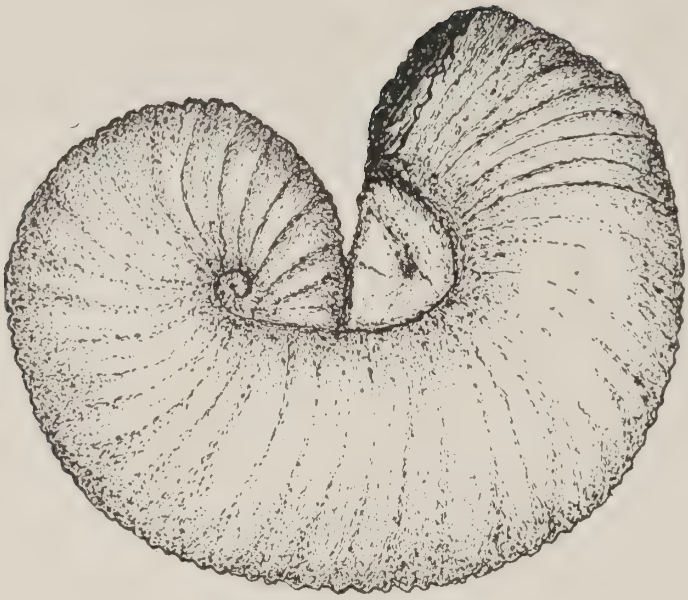
One remarkable fact in connection with the development of the genus Scaphites is that its greatest development in both Europe and America took place in a region lying between parallels 40° and 50° of latitude. This may be only a coincidence, or it may be that when the paleontology of the now unknown regions is thoroughly worked out the present conditions will be found to be only apparent and not the real ones. If neither of these assumptions be correct the explanation may be found to lie in the similarity of environments.

The following is the distribution of the species of the genus Scaphites. In Europe, *S. æqualis*, *S. obliquus*, *S. texanus*, *S. conradi*, *S. nicolleti*, *S. hippocrepis*, *S. hugardianus*, *S. ivanii*, *S. compressus*, *S. constrictus*, *S. culvieri*, *S. reiformis*, *S. geinitzi*, *S. inlatus*, *S. multinodosus*, *S. nodifer*, *S. ornatus*, *S. quadrispinosus*, *S. tridens*, *S. tuberculatus*, *S. trinodosus,* India, *S. æqualis*, *S. obliquus*, *S. kingianus;* North America, *S. warreni*, *S. conradi* (3 varieties), *S. larvæformis*, *S. vermiformis*, *S. texanus*, *S. nodosus* (3 varieties), *S. mullanus*, *S. subglobosus*, *S. nicolleti*, *S. cheyennensis*, *S. abyssinus*, *S. iris*, *S. mandanensis*, *S. hippocrepis*, *S. culvieri*, *S. quatsinœnsis*, *S. reniformis*, *S. semicostatus*, *S. vermiculus*, *S. verrucosus*, *S. comprimus*.

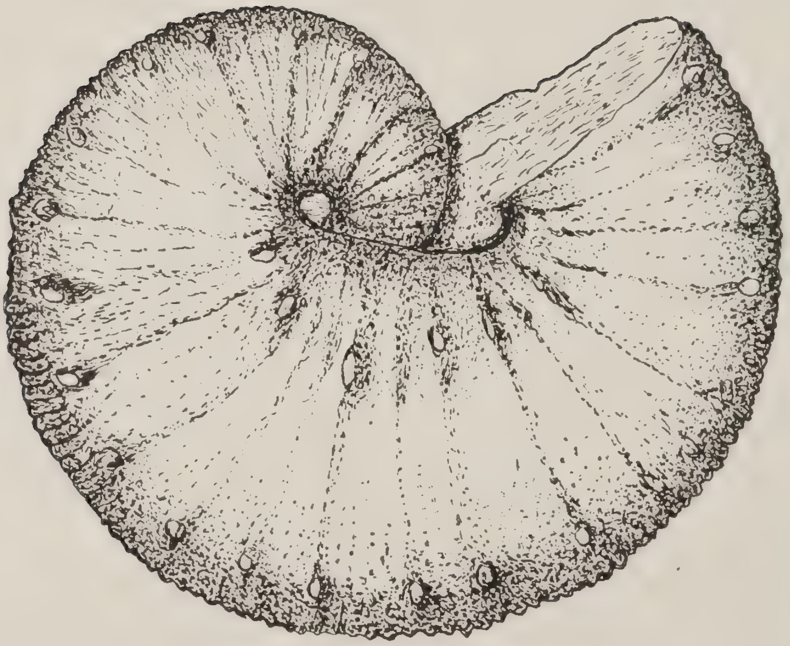
ONTOGENY, PHYLOGENY AND PALEONTOGENY. No description of the ontogeny or phylogeny of the genus Scaphites has as yet been published. As the adult forms of the majority of the species show evidences of a degenerative character, it was supposed that the genus was an abnormal type, and further that the individual did not per-

LIBRARY
OF THE
UNIVERSITY of ILLINOIS.

1



2



EXPLANATION OF PLATE XXII.

SCAPHITES WARRENI. (Mus. No. P 5940.)
Fig. 1. Side view of specimen.

SCAPHITES NODOSUS.
Fig. 2. Side view of specimen.

petuate racial characteristics. That these suppositions do not accord with the facts is a further confirmation of one of the laws of evolution. It is confirmatory of the law that as characters of development first show themselves in the adult, so also do degenerative characters. In other words degeneration takes place in the inverse order of development. The order of development of the Cephalopods, as shown by Hyatt, has been in regard to form: 1. the straight shell; 2. the arcuate shell; 3. the loosely coiled shell; 4. the closely coiled shell. Along with this development of the form of the shell has gone an increased development in the complexity of the sutures. Scaphites is considered degenerative in form because of the tendency exhibited in the adult to return to an early form by a partial uncoiling of the shell. If this be true degeneration, it has not as yet affected the sutures.

In fact the phylogeny of the genus reveals progression rather than retrogression. As an illustration compare the suture of *Scaphites warreni* Meek, Fig. 1, Pl. XXII with the suture line of *Scaphites nodosus* Meek, Fig. 2, Pl. XXII.

The first is a Benton species while the second is a Pierre species. The first, therefore, is the primitive form as regards time and suture. Furthermore the ontogeny of *S. nodosus* reveals a stage which corresponds with reference to the suture very closely to the adult suture of *S. warreni*. It seems very probable, then, that the latter is in the line of the direct evolution of the former and represents an earlier stage. The changes in form as revealed by the two species do not point to any marked degree of retrogression. The principal changes have been an increase in the size of the individual; an increase in the complexity of the suture lines; and the development of two rows of nodes, one on the umbilical shoulder and a second on the ventral border. In *S. warreni* the ornamentation consists of strong ridges with a tendency toward nodosity in some individuals. In the young of *S. nodosus* the ridges are well marked while the nodes are entirely absent on the umbilical shoulder and not prominent on the ventral border.

In the excellent work of Branco although Scaphites is mentioned in the list of genera its ontogeny is not exhibited. The omission was no doubt due to a lack of workable material. And, indeed, this was at first a serious obstacle to the success of the present writer. Owing to the highly crystalline character of the calcium carbonate which preserved the form of the shells many specimens were broken up without results. Later, from some young forms furnished by Prof. Weller, of the University of Chicago, the results recorded below were obtained. Some of the specimens although entirely opaque in the outer whorls were very translucent in the inner whorls so that the suture lines were easily discernible.

Fig. 1, Pl. XXIII, represents a number of sutures as follows: *a.* The first suture is angustisellate and represents the ananepionic stage. *b.* The second suture is a transition from the suture of Anarcestes to that of Tornoceras. *c.* The third suture is Tornoceras. *d.* The fourth suture is a transition from Tornoceras to Glyphioceras, or possibly Prionoceras. *e.* The fifth suture is Glyphioceras. *f.* Is Glyphioceras. *g.* Is a suture on the second whorl which is Gastrioceras but is just approaching Paralegoceras. *h.* Is a suture on the third whorl, diameter 5mm., and is the ammonitic radical, probably nearest Pronorites.

The suture on the first part of the fourth whorl has much the appearance of the suture of *S. warreni*, and toward the end of that whorl reaches the adult form.

In Figs. 2, 3 and 4, Pl. XXIII, views of the protoconch are given which represent the phylembryonic stage of the type *Scaphites nodosus* Meek.

Figs. 7–12, Pl. XXIII, represent six stages of growth between the close of the brephic and the beginning of the ephebic stage.

Fig. 5, Pl. XXIII, shows the suture of the adult form of *S. warreni*, and Fig. 6 that of *S. nodosus*, Museum specimen No. 3653, University of Chicago.

SCAPHITES WARRENI—MEEK.

PROC. ACAD. NAT. SCI. OF PHILA., P. 185. 1860.

(Pl. XXII, Fig. 1 and Pl. XXIII, Fig. 5. Mus. No. P 5940.)

REVISED AND ENLARGED DESCRIPTION. "Shell medium size, transversely subovate, moderately compressed, inner volutions nearly circular, closely involute, and composing a little more than one-half the bulk; deflected body portion longer than the diameter of the involute portion and rather more proportionally than the inner turns; surface costate and without proper nodes; costæ small on the inner whorls, where they do not differ materially in size, but on the body part some, usually every third or fourth one, become more prominent than the others, and extend entirely across from the inner side to and over the periphery, in passing upon which they bifurcate, or give off branches and assume, with these, a uniform size. The aperture

EXPLANATION OF PLATE XXIII.

SCAPHITES NODOSUS—Meek.

Fig. 1. Views of sutures.

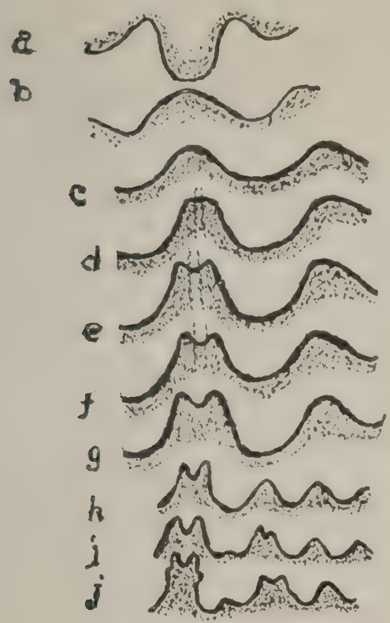
Figs. 2, 3 and 4. Views of protoconch.

Fig. 5. Suture of *S. warreni.*

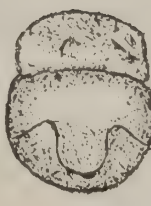
Fig. 6. Suture of adult *S. nodosus.*

Figs. 7–12. Young individuals.

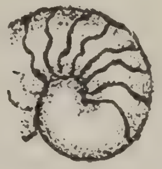
1



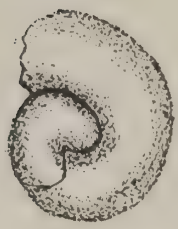
2



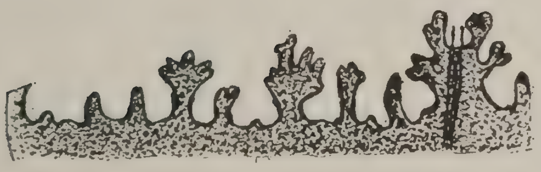
3



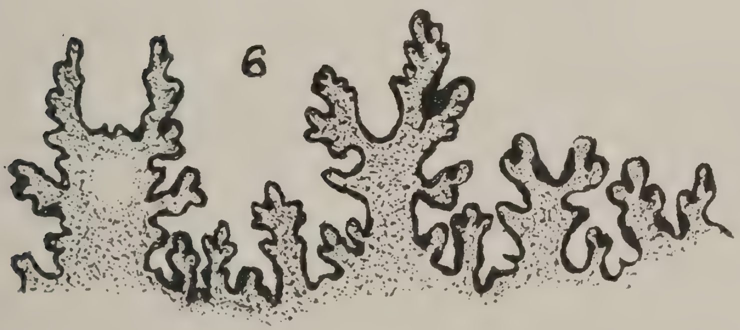
4



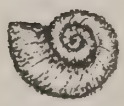
5



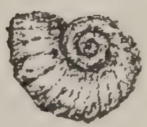
6



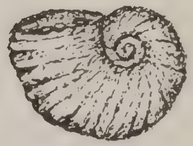
7



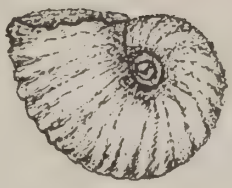
8



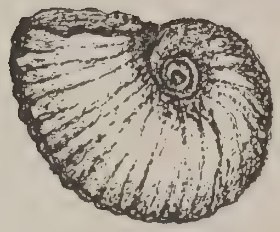
9



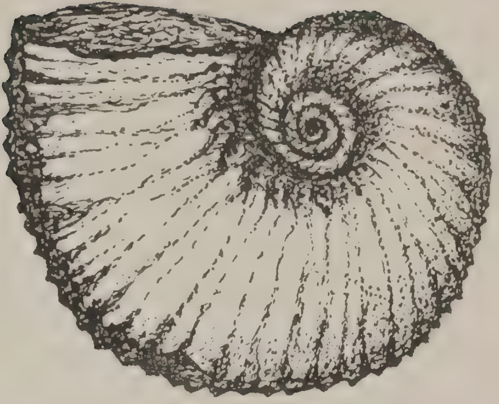
10



11

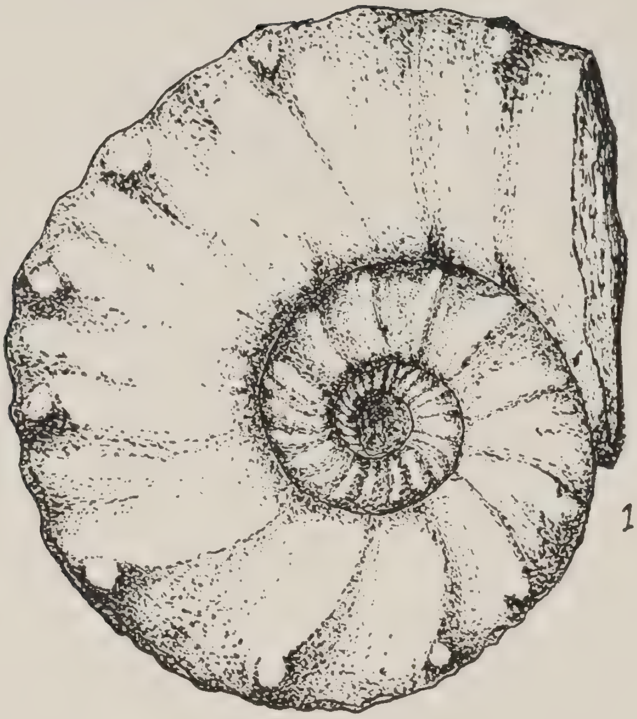


12

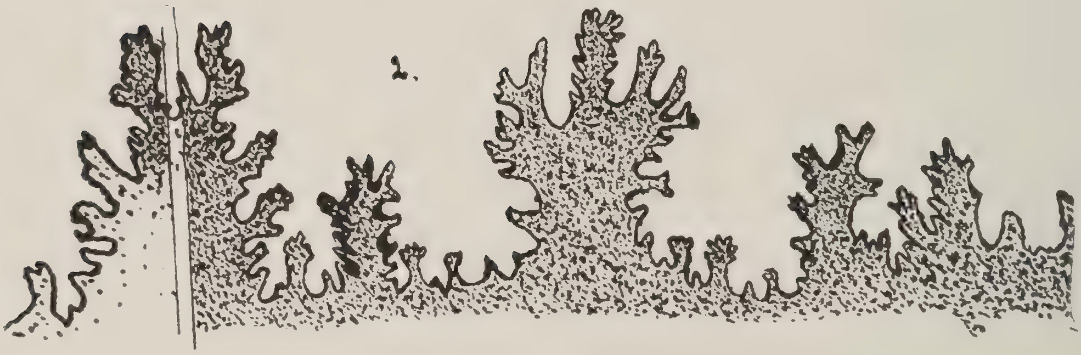


LIBRARY
OF THE
UNIVERSITY of ILLINOIS.

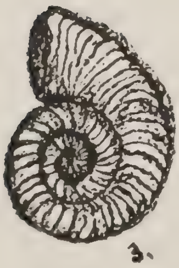
LIBRARY
OF THE
UNIVERSITY of ILLINOIS.



1.



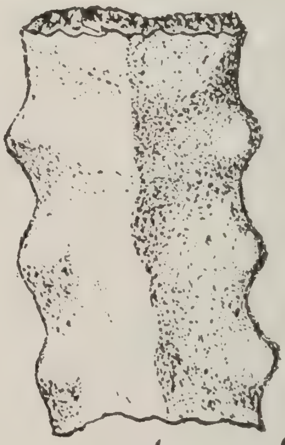
2.



3.

4.

5.



6.

EXPLANATION OF PLATE XXIV.

PRIONOTROPIS WOOLGARI—Meek. (Mus. No. P 5931.)

Fig 1. Side view of specimen.
Fig. 2. View of suture.
Fig. 3. Side view of young specimen.
Figs. 4 and 5. Cross section of young specimen.
Fig. 6. Dorsal view of specimen.

[illegible] 1—Me[illegible] (Mus. No[illegible]

[illegible] specimen.

[illegible]

is oval in form with a smooth periphery; it is turned inward toward the coil of the shell.

"Septa are provided with moderately broad lobes and sinuses. The siphonal lobe is longer than wide, and bears two rather prominent lateral branches, each of which is unequally bifid, and digitate. The first lateral sinus is about the size of the siphonal lobe and has approximately the same width at the base; it is divided at its extremity into two unequal lobes both of which are bifid, the one nearest the siphonal lobe having its lobes again subdivided; first lateral lobe, about the size of the siphonal lobe, divided at its extremity into two tripartite lobes each of which is digitate; second lateral sinus shallow, divided into two rounded lobes each of which is slightly indented; second lateral lobe tripartite, central division not divided, other two bifid; third lateral sinus small bifid; remaining portion of septa not visible."

Suturally our type is very closely allied to *S. ventricosus* Meek, and it is quite probable if they do not belong to the same species that they are varieties of the same species. The specimen here described is much larger than Meek's type of *S. warreni*, but it has the same general form. It resembles the former species in aperture and suture, and the latter in body shape and costæ. It is the belief of the writer that *S. warreni*, *S. wyomingensis* and *S. ventricosus* are varieties of the same species.

PRIONOTROPIS WOOLGARI—MEEK.

U. S. GEOL. SURVEY OF THE TERRITORIES, VOL. IX, P. 455. 1867.

(Pl. XXIV, Figs. 1 to 6. Mus. No. P 5931.)

Further collecting and study of this form may reveal a new species. A comparison of the suture of *P. woolgari* with the suture of the form here figured and placed provisionally in the above species reveals many differences. However, these differences may be only such as exist between the young and the adult individuals of the same species. As the sutural differences seem to be the only well marked ones the original description will be given here and the reader asked to make the comparison of the figures.

"Shell attaining a medium size, more or less compressed discoidal, the outer turn being proportionally more convex (including nodes) than those within; each volution embracing about one-fifth of the next within, and having its umbilical margin slightly indented by the uncovered nodes forming the inner of the two outer rows on the succeeding volution within; umbilicus about equaling the greatest dorso-ventral diameter of the last turn. Young examples, half an inch to one inch in diameter, with costæ linear, closely arranged, of nearly uniform size, and manifesting scarcely any tendency to develop nodes but already showing the forward curve of their outer ends well defined, while the peripheral keel is low, narrow and simple, and the furrow on each side shallow. At a somewhat larger size, costæ usually more or less unequal in size, the larger ones now beginning to develop the two nodes at their outer curved ends, and to become a little more prominent and compressed at their inner extremities, while the rather more prominent keel begins to develop its crenate outline, and the nodes nearest to assume their compressed form and parallel arrangement. On attaining to two and one-half to three inches in diameter, costæ, nodes and keel become more prominent, the latter being strongly compressed and deeply and largely scalloped, with divisions rounded in outline; while at this stage of growth the periphery, as seen in profile, would seem to be very deeply sulcated on each side of the keel, but this is due to the prominence of the row of nodes on either side of the same. Costæ, when the shell has attained a diameter of four inches much depressed in the middle, with the nodes at their inner ends thicker and more obtuse, and those nearest the keel more depressed or nearly obsolete, while those of the third series, near by, become much enlarged and produced obliquely outward as short, thick, spine-like projections. Soon the outer compressed nodes disappear, and the keel is only represented by separated, low, elongated nodes; and when the shell has attained a diameter of seven inches, the costæ are more distant, greatly elevated, compressed, and almost wing-like, but still retain a large, prominent, subtrigonal node or projection at their outer ends, and again become, as it were, pinched up at their inner extremities, which do not quite reach the umbilical margin.

"Septa moderately close together; siphonal lobe longer than wide with three or four short branches on each side, the two terminal of which are largest, more or less nearly parallel, and merely serrated; first lateral sinus broader than the siphonal lobe, more or less deeply divided into two subequal branches with short, irregular branchlets and digitations; first lateral lobe somewhat longer than the siphonal, and tripartite, with short, irregular branchlets and digitations occasionally in small specimens, with the middle terminal branch proportionately broad and so deeply sinuous at the end as to impart more nearly the appearance of a bipartite arrangement of the whole; second lateral sinus nearly resembling one of the divisions of the first, and in the adult with merely a number of marginal digitations; second lateral lobe little more than one-third as long, and from one-third to one-half as wide as the first, generally tripartite at the end, but sometimes in large specimens, bipartite on one side of the shell, the divisions being very simple and short, or serrated; third lateral sinus very small and merely bilobate, or in large specimens digitate along the margins; third lateral lobe hardly half as long as the second, and in small specimens merely tridentate at the end."

The suture, shown in Fig. 2, Pl. XXIV, is from a specimen evidently much larger than any seen by Meek. The diameter of the septate portion is more than two inches and although the non-septate part is not known it is probably at least three inches in diameter. The specimens here figured were collected from the Blue Hill shales of the Benton, in Osborne County, Kansas.

THE GENUS OSTREA.

The genus Ostrea has many representatives in the strata of the Cretaceous System, although the entire system comprises a part only of its geological range. Its distribution was as wide as the distribution of the genus to-day plus its distribution in the epicontinental seas. A few species are common to Asia, Europe, Africa and North America. Five species are common to Africa, Europe and North America. Fifteen species found in Africa are also found in Europe. One species not found in Europe is common to Africa and North America. The Lower Cretaceous seas furnished the greatest abundance of species and individuals.

During middle Upper Cretaceous times the waters of the American epicontinental seas were too clear or lacked some characteristic conducive to the life of Ostreæ, for few species or individuals are present in the strata except a very small form which was probably able to adjust itself to the environments. This species, *Ostrea congesta,* is one of the best known and most widely distributed of the genus. It is remarkable also for its abundance.

Probably the greatest beds of fossil Ostrea in existence are in the Lower Cretaceous strata of Texas. There beds of almost pure shells several feet in thickness, having a meagre arenaceous matrix, are traceable for miles. Farther north in Kansas they still form the most abundant types.

OSTREA BELOITI, *n. sp.*

(Pl. XXV, Figs. 7 and 8. Mus. No. P 5944.)

Shell thin, oblong, moderately capacious, and possessing more than ordinary symmetry. Beaks are long and sharply pointed; fitting closely. Lower valve deep; area broad, triangular, with rounded borders, possessing a slight depression in the posterior-central portion; posterior border, rounded; anterior border, pointed; dorsal border, slightly concave, nearly straight; ventral border, convex.

Upper valve, flat or slightly convex transversely; in general outline it is very similar to the lower valve; area much the same, perhaps a little shorter. Muscular impression in both valves, sub-central and indistinct. Surface not rough or but little imbricated.

Dimensions—Length, 45mm.; width, 25mm.; height, 8mm.

The species occurs in the Lincoln Marble horizon of the Benton. It is not abundant and has been collected from two localities only. The specimen here described was collected from an outcrop on the Solomon river in the Kansas area.

FASCIOLARIA *sp.*

(Pl. XXV, Figs. 1 and 3. Mus. No. P 5941.)

Shell a little more than moderate size, stout fusiform; spire consisting of three rather convex volutions. The body whorl large and possessing in the central region a flat area; whorl merging into a rather short canal which is slightly curved; last whorl (body) and canal more than equalling the length of the spire. Surface ornamentation not distinct in specimen, hence the difficulty of determining the species.

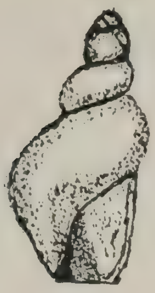
Several fragmentary specimens which probably belong to the genus Fasciolaria were collected by the writer from the septaria of the Blue Hill shales (Benton). The material is in such a condition as not to warrant specific determination. They are figured and mentioned only for the purpose of making our literature as complete as possible and with the hope that in the future better material may be obtained through the suggestion of the presence of such forms.

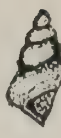
EXPLANATION OF PLATE XXV.

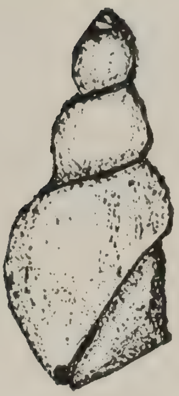
FASCIOLARIA, *sp.* (Mus. No. P 5941.)
  Fig. 1. Cast of a small specimen.
  Fig. 3. Cast of a larger specimen.

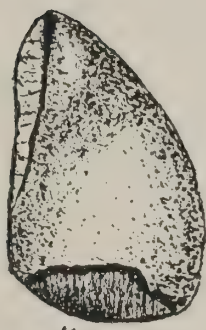
FUSUS, *sp.* (Mus. No. P 5942.)
  Fig. 2. Cast of small specimen.
  Fig. 5. Cast of type specimen.
  Figs. 4 and 6. Views of an indeterminable Gastropod.

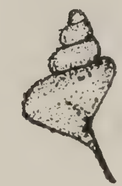
OSTREA BELOITI, *n. sp.* (Mus. No. P 5944.)
  Fig. 7. Interior view of left valve.
  Fig. 8. Interior view of right valve.

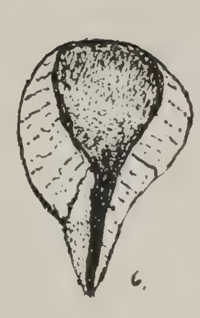

1

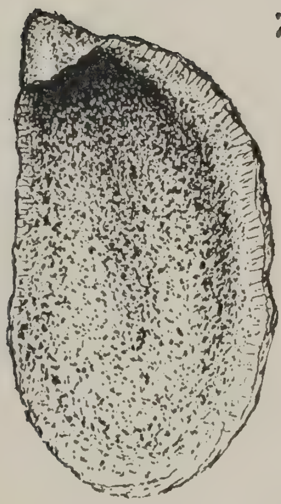

2.

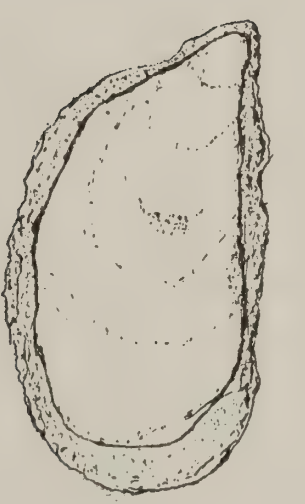

3.


4


5

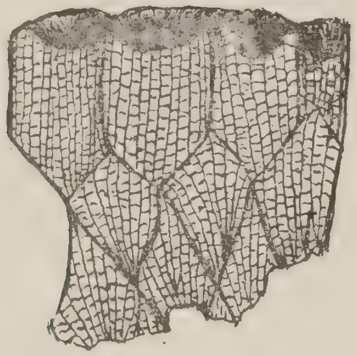

6.


7.

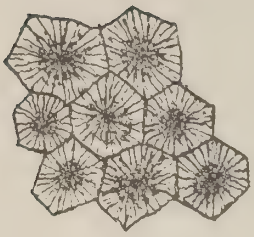

8.

LIBRARY
OF THE
UNIVERSITY of ILLINOIS.

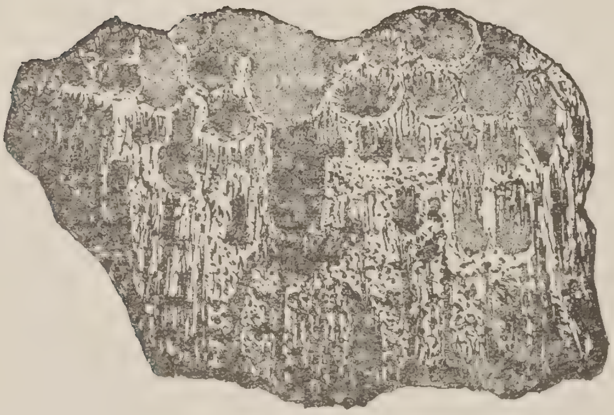
LIBRARY
OF THE
UNIVERSITY of ILLINOIS.



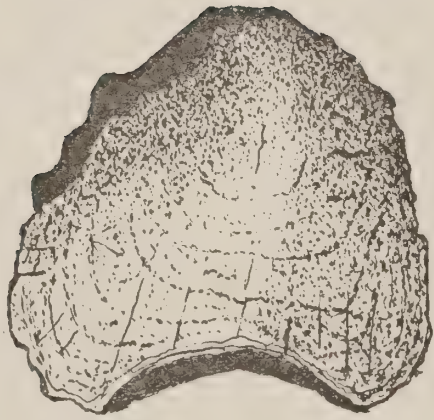
1



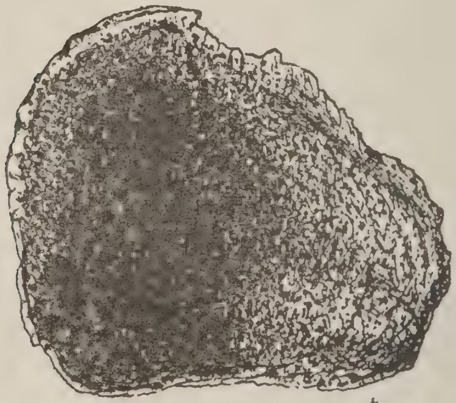
2.



3.



4



5

EXPLANATION OF PLATE XXVI.

ASTROCŒNIA CONICA, *n. sp.* (Mus. No. P 5946.)
Fig. 1. A longitudinal section of type.
Fig. 2. A transverse section of type.
Fig. 3. A fragment of corallum—type.

PSEUDO-PERNA WILSONI, *n. sp.* (Mus. No. P 5945.)
Fig. 4. Exterior view of left valve.
Fig. 5. Interior view of left valve.

FUSUS *sp.*

(Pl. XXV, Figs. 2 and 5. Mus. No. P 5942.)

The shells of these specimens are entirely absent and a specific determination is not warranted upon evidences such as are presented by casts alone. The reader is asked to compare the figures of these specimens with the figures of *Fusus staminea*, Conrad. The forms represented here were found associated with *Rostellites*, and the above described species.

ASTROCŒNIA CONICA, *n. sp.*

(Pl. XXVI, Figs. 1, 2 and 3. Mus. No. P 5946.)

Corrallum tuber-like, about the size of a medium-sized orange; corallets inversely conical, not greater than 8mm. in diameter, calices of the corallets of moderate depth, six sided but not always distinctly so, with moderately thin interstices but bordering each other; columella distinct but not prominent; intersection of dissepiments and septæ forming prominent carinæ; vertical septæ extending more than half the distance to the columella, the secondary ones only about half the length. Specimen somewhat weathered so that generic characters are doubtful.

This specimen is interesting as being the only species of coral as yet described from the Benton of the Interior Cretaceous. It was collected by the writer from the Lincoln Marble horizon on Rattlesnake creek in Mitchell County, Kansas.

PSEUDO-PERNA WILSONI, *n. sp.*

(Pl. XXVI, Figs. 4 and 5. Mus. No. P 5945.)

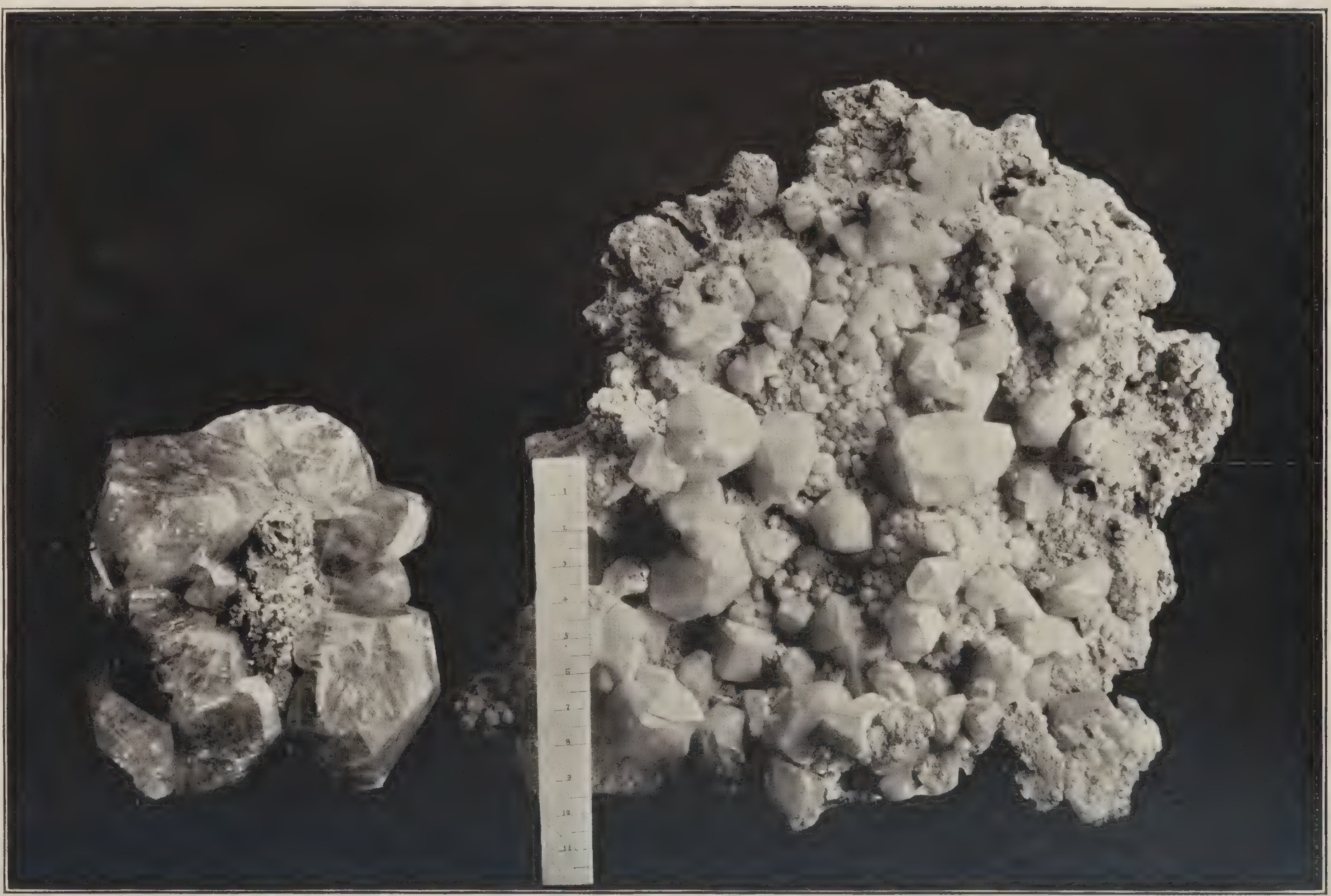
Shell thin, capacious, triangular in general outline with short beaks turned slightly toward ventral border, and fitting closely. Lower valve thick on the margins, thin centrally; not as capacious as upper valve and nearly flat on the adhering surface; fluted on margin in some specimens, and lacking the symmetry of outline noted in upper valve; ventral border possessing a triangular excursion near the central portion; dorsal border, concave; posterior border, convex.

Upper valve, flat or nearly so on postero-ventral wing, convex in general; ventral margin in region of beak crossed by slight ridges of muscular attachment; area small and depressed; muscular impression prominent and possessing fine striæ concentrically arranged; dorsal border convex; ventral border nearly straight, somewhat wavy; posterior border concave; shell becoming very thin at the margins; exterior surface, marked by fine wavy concentric lines of growth which are cut transversely by slight depressions or partings of the shell; interior smooth, corneous.

Dimensions—Length, 38mm.; width, 42mm.; height, 10mm.

This species occurs in the Hesperonis beds of the Niobrara. It was collected from the outcrops on the Smoky Hill river in the Kansas area.

LIBRARY
OF THE
UNIVERSITY of ILLINOIS.



GROUPS OF CALCITE FROM JOPLIN, MISSOURI.

The crystals of the smaller specimen are of Type 1, those of the larger of Type 3.

FIELD COLUMBIAN MUSEUM
PUBLICATION 44.
GEOLOGICAL SERIES. VOL. I, NO. 7.

I.

NEW MINERAL OCCURRENCES.

II.

CRYSTAL FORMS OF CALCITE FROM JOPLIN, MISSOURI.

BY
OLIVER CUMMINGS FARRINGTON, PH.D.,
Curator, Department of Geology.

CHICAGO, U. S. A.
February, 1900.

ERRATA.

Publication 44, Geological Series, Vol. 1, No. 7.

Fig. 2 should stand so that the edges ab, bá, etc. are vertical.

Fig. 6 should stand at right angles to the position given.

p. 236, line 7. For $4\bar{1}\bar{3}5$ read $\bar{3}4\bar{1}5$.

line 8. For $5\bar{1}\bar{4}3$ read $4\bar{1}\bar{3}5$.

p. 241. The symbols $+\ \frac{2}{5}\ R\ 2$ and $+\ \frac{1}{4}\ R\ 3$ should stand opposite the letters *w* and *t* respectively.

TABLE OF CONTENTS.

NEW MINERAL OCCURRENCES, - - - - - - 221

Inesite, - - - - - - - - - - 221

Caledonite, - - - - - - - - - 224

Gay-Lussite, - - - - - - - - 226

Epsomite, - - - - - - - - - 228

Golden Calcite, - - - - - - - 229

Dolomite Used as Indian Money, - - - - - 230

CRYSTAL FORMS OF CALCITE FROM JOPLIN, MO., - - - 232

Localities of Large Crystals, - - - - - - 232

Forms of Large Crystals, - - - - - - 233

Forms of Smaller Crystals, - - - - - - 237

Forms of Twinned Crystals, - - - - - - 238

NEW MINERAL OCCURRENCES.

INESITE.

SAN CAYETANO MINE NEAR VILLA CORONA, STATE OF DURANGO, MEXICO.

MUSEUM No. M 5889.

A specimen of inesite from the above locality was first secured by the writer in the spring of 1896 while at Villa Corona. Having later determined the mineral by its blowpipe characters as inesite, a request was sent to Mr. John D. Almy, one of the proprietors of the mine, to procure more specimens if possible. Through his kindness, and that of Mr. W. H. Schlemm, a few more specimens were obtained, and were generously placed at the writer's disposal for study. The rarity of the mineral makes the find of interest, as it is known at only three other localities in the world, viz.: The manganese mines at Nanzenbach, northeast of Dillenburg, Germany; the Harstig mine, Pajsberg, Wermland, Sweden,* and Jakobsberg, Nordmark, Sweden.† In the specimens from the San Cayetano mine the mineral occurs partly in cavities and partly intergrown with calcite and a flesh-colored manganesian calcite. These fill narrow veins in what is probably an altered andesite. The inesite occurs in tufts of radiating crystals which are of the characteristic flesh-red color. The most characteristic pyrognostic reaction of the mineral, noted by the writer, is, that when heated in the closed tube it becomes opaque, gives off water, and falls to powder. The crystals are of slender, prismatic habit, averaging about 5 mm. in length. None were found doubly terminated, the attachment at one end preventing the development of faces there. A total of seven forms was identified, as follows:

a (100), *b* (010), *c* (001), *g* (201), *d* ($0\bar{1}1$),
k (11.0.12), and *s* (946).

Of these the forms *k* (11.0.12) and *s* (946) are new. The form *k* occurred on several crystals, the form *s* was found on but one. The table following gives the measurements by which these forms were identified, together with measurements of the other forms noted. The calculated values given with them are deduced from Scheieb's ratios as quoted by Dana.*

---

*Dana's Mineralogy, Sixth Edition, p. 564.

†First Appendix to Dana's Mineralogy, 1899.

	No. of Measurements.	Limits.	Observed.	Calculated.
$c : s = 001 : 946$	1		34°	34° 10′
$g : s = 201 : 9\bar{4}6$	1		13° 23′	13° 30′
$a : s = 100 : 9\bar{4}6$	1		19° 47′	19° 48′
$d : s = 0\bar{1}1 : 9\bar{4}6$	1		45° 20′	45° 21′
$b' : s = 0\bar{1}0 : 9\bar{4}6$	1		84° 30′	84° 33′
$c : k = 001 : \overline{11}.0.12$	3	79° 48′—80° 42′	80° 26′	80° 9′
$k : a' = \overline{11}.0.12 : \bar{1}00$	3	52° 36′—55° 34′	52° 25′	53° 9½′
$a : g = 100 : 201$	6	11° 47′—12° 27′	12°	12° 5′
$g : c = 201 : 001$	6	34° 36′—35° 9′	34° 36′	34° 36½′
$b' : d = 0\bar{1}0 : 011$	4	48° 27′—50° 40′	48° 34′	49° 23′
$d : c = 0\bar{1}1 : 001$	4	46° 25′—46° 30′	46° 30′	47° 22′
$c : b = 001 : 010$	4	82° 48″—84° 35′	82° 50′	83° 15′
$a : b = 100 : 010$	4	80° —86° 33′	82° 30′	82° 35′
$b : a' = 010 : \bar{1}00$	4	97° 25′—100°	97° 25′	97° 25′

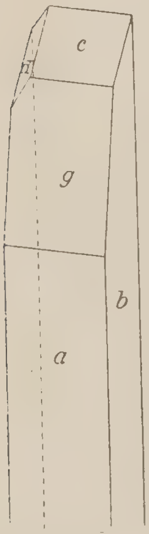


FIG. 1—Inesite.

The crystal faces were found in general to be fairly flat and bright, except the clinopinacoids, which were always vertically striated, so that no very satisfactory measurements could be made from them. The usual habit and development of the crystals is illustrated in Fig. 1. Fig. 2 shows a completed crystal giving the new forms, *k* ($\overline{11}.0.12$) and *s* ($9\bar{4}6$) in their relative development.

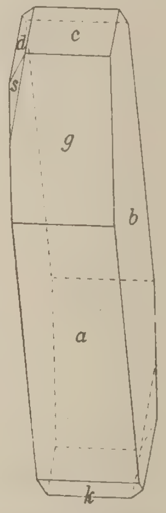


FIG. 2—Inesite.

An analysis of the mineral was made by the writer. For this purpose about two grams were laboriously separated from the calcite in which it was largely embedded. Experiments were first made upon the temperature at which water was driven off in order to determine, if possible, the nature of its existence in the mineral. About a gram of the finely powdered mineral was heated at successively increasing temperatures until practically constant weight was obtained at each. The following are the percentages of loss obtained: At 110°, 3.88%; at 240°, 1.94%; at 310°, 0.10%; at faint redness, 1.00%; total, 6.92%. Of the above amount, 5.99% was taken up again by the mineral on exposure to ordinary air. This amount may, therefore, be regarded as water of crystallization. On continuous heating at faint redness, the mineral turned dark and showed a gain in weight doubtless from oxidation of manganous compounds. It was evident, therefore, that water could not be correctly determined by loss upon ignition.

---

*Dana's Mineralogy, p. 565.

A direct determination was made, therefore, upon a separate portion by Penfield's method,* a blast lamp being used for the final heating. This determination gave 8.20% of water. It could be distinctly seen on application of the higher heat of the blast lamp that more water was given off at the high temperature, showing beyond question that some of the water was present as water of constitution. If the percentage of water taken upon exposure to air, 5.99%, be regarded as water of crystallization, then the remainder, 2.21%, may be considered to denote the percentage of combined water. This agrees well likewise with Bärwald's observations, he having found 1.97% of water given off above 300°. It is evident from the above experiments also that determination of water as loss upon ignition would certainly give too low a result. This may account for the low percentage, 7.17%, obtained by Flink.

The remainder of the analysis was performed by the methods commonly employed for the analysis of silicates. A sodium carbonate fusion was made, the bases separated from silica by solution with hydrochloric acid, iron precipitated by ammonia, manganese by bromine and calcium by ammonium oxalate. Results of the analysis with ratios are as follows:

		Ratio		
SiO_2	44.89	748	748	1.64
MnO	36.53	517	699	1.53
FeO	2.48	034		
CaO	8.24	148		
MgO	tr.			
H_2O cryst	5.99	336	456	1.
H_2O const	2.21	120		
	100.34			

Sp. Gr. (det. by Thoulet's solution)=2.965.

The ratio of $SiO_2 : RO : H_2O$ is thus nearly 1.5 : 1.5 : 1. Considering the ratio of water of crystallization to water of constitution = 3 : 1, and of Mn : Ca = 4 : 1, the formula can be expressed as

---

*Amer. Jour. Sci., 3rd Ser., Vol. 48, p. 30.

$4\ H_2O$, $6\ (Mn, Ca)\ O$, $6\ Si\ O_2$, or $H_2\ (Mn, Ca)_6\ Si_6\ O_{19} + 3H_2\ O$. Comparing the percentages called for by the formula, with the writer's analysis calculated to 100% (reckoning Fe O as Mn O), the results are as follows:

	Theory.	Analysis Calculated to 100.
$6\ Si\ O_2$	42.91	44.76
$\frac{4}{5}\ (6\ Mn\ O)$	40.51	38.86
$\frac{1}{5}\ (6\ Ca\ O)$	8.00	8.21
$4\ H_2\ O$	8.58	8.17
	100.	100.

Here the greatest discrepancy to be noted is in the percentage of $Si\ O_2$, which is noticeably higher in the analysis than the theory calls for. Mn O is also a little lower. Yet it is believed that this formula better agrees in general with analyses of the mineral and better expresses its constitution than any hitherto proposed. Flink's formula, $2\ (Mn, Ca)\ Si\ O_3 + H_2\ O$, reckons all the water as water of crystallization, which is clearly incorrect. Moreover, the percentage of Mn O called for by his formula, 41.4%, is larger than has ever been obtained. Bärwald's formula, $R\ (R\ O\ H)_2\ Si_3\ O_8 + aq.$, gives percentages nearly like that proposed by the writer, but the compound represented by such a formula would less resemble other zeolites in manner of constitution than does that of the writer's formula. Moreover, one would expect a darker color if the molecule Mn OH were present in the mineral.

CALEDONITE.

STEVENSON-BENNETT MINE, ORGAN MTS., NEAR LAS CRUCES, NEW MEXICO.
MUSEUM No. M 5486.

A single specimen of this mineral was picked up by the writer on the dump of the Stevenson-Bennett mine in the spring of 1896. It is the only specimen ever found there, so far as I am aware. It is also the second or possibly the third occurrence of the mineral reported in America. It is known to occur* at the Cerro Gordo mines in California, and has been reported from Mine la Motte, Missouri, but the report needs confirmation. In the specimen secured by the writer the mineral is in the form of several distinct crystals which occur on a piece of the quartz gangue common at the mine. With the caledonite crystals are associated crystallized cerrusite, massive galena, linarite, and wulfenite. One of the crystals of caledonite is of good size, being 5 mm. in length in the direction of the vertical axis, and 3 mm. in length in the direction of the macrodiagonal axis. The other crystals are smaller. All are developed prismatically in the direction of the brachydiagonal axis, and are attached by its extremity. The crystals are of a deep bluish-green color and transparent. They are penetrated to some extent by cerrusite, which shows as darker spots when seen under a lens. These portions also turn brown when fragments of the mineral are heated in the closed tube. Other pyrognostic characters of the mineral, noted by the writer, which may be added to those given by Dana, are: In the closed tube it decrepitates, becomes black and opaque, and gives off water. Fuses easily B. B. with intumescence to a black globule.

---

*Dana's Mineralogy, p. 925.

The crystals were fairly well suited for goniometric measurement, and the following forms were found, the position and lettering being that given by Dana:

b (010)
c (001)
m (110)
x (201)
f (012)
e (011)
s (223)
t (221)

The development of the different crystals was found to be quite constant, the prominent forms being *c*, *b*, *m* and *s*. The most perfect crystal was considerably striated parallel with the direction of the brachydomes, also in the direction of the zone of the pyramids and prism. Owing to these striations but few really accurate measurements could be obtained, but a few were secured which are of interest as supporting the correctness of the ratios obtained by Busz* from a study of the caledonite of Leadhills. The following are the measurements which it was possible to make with accuracy, and for comparison are given the values as calculated by Busz:

	Measured.	Calculated.
$b : m = (010) : (110)$........................	47° 26′	47° 25′ 30″
$m : m''' = (110) : (1\bar{1}0)$........................	85° 12′	85° 9′
$s : s''' = (223) : (2\bar{2}3)$........................	66° 35′	66° 30′ 34″
$c : x = (001) : (201)$........................	71° 52′	71° 53′
$x : x' = (201) : (20\bar{1})$........................	36° 15′	36° 14′

The crystals were carefully studied also in the hope that some measurements might be found which would throw some light on the disputed question as to whether the mineral crystallizes in the orthorhombic or monoclinic system. Owing, however, to the incompleteness of the crystals on account of their attachment, or to the striations on the faces, only one reliable set of measurements bearing upon this point could be obtained. These were measurements of the zone $c:x:x':c'=(001):(201):(2\bar{0}1):(0\bar{0}1)$, as already quoted. Completing this zone by difference, the angles are:

**Neues Jahrbuch fur Min. Geol. u. Pal. 1895, Band I, p. 111.*

$c:x=(001):(201)=71^\circ\ 52'$.

$x:x'=(201):(20\bar{1})=36^\circ\ 15'$.

$x:c'=(20\bar{1}):(00\bar{1})=71^\circ\ 53'$.

Thus the brachydiagonal is an axis of binary symmetry and the mineral must be regarded orthorhombic. As noted by Busz also, the habit of the crystals gives the impression of orthorhombic symmetry.

The usual development of the crystals is shown in Fig. 3. That shown in the direction of the brachydiagonal is necessarily estimated, as no crystals doubly terminated in the direction of this axis were found. The general resemblance in habit to that of cerussite from Rezbanya* figured by Schrauf will be noted.

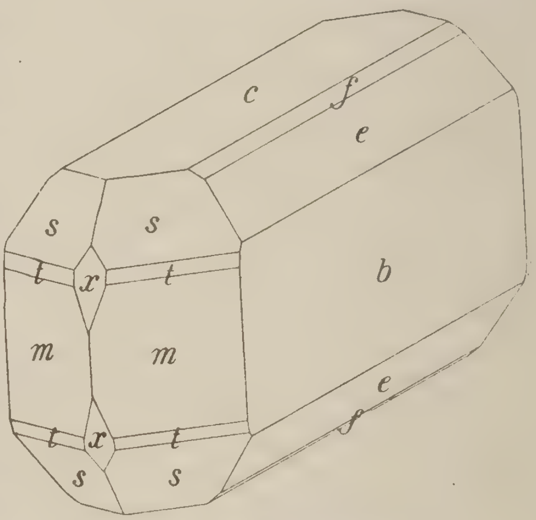


FIG. 3—Caledonite.

GAY-LUSSITE.

SWEETWATER VALLEY NEAR INDEPENDENCE ROCK, WYOMING.
MUSEUM No. E 9696.

On dissolving in water the native carbonate of soda found in the Sweetwater Valley, Wyoming, a residue of clay and minute crystals is left. Some of the latter were kindly forwarded to the writer by Prof. W. C. Knight of the University of Wyoming, who was the first to notice the crystals, so far as I am aware. A test of the pyrognostic and crystallographic characters showed the crystals to be undoubtedly gay-lussite. They are microscopic in size, none that I found being as large as the head of an ordinary pin. More exactly, none exceed one millimeter in the direction of greatest length. They are colorless and transparent and remain so with the exception of a slight deliquescence on exposure to air. In distilled water, however, they turn white and in a short time become pulverulent from solution of sodium carbonate. The crystal forms are well developed and the faces fairly sharp and bright. In habit the crystals are somewhat different from any heretofore described on account of the relative subordination of *e* (011) and the relative greater prominence of *r* ($\bar{1}12$) and *c* (001).

---

*Dana's Mineralogy, p. 287.

The following forms were found :

c (001), *m* (110), *e* (011), *r* ($\bar{1}12$).

They were identified by the following measurements :

	No. of Measurements.	Limits.	Observed.	Calculated.
$m:m'''=110:1\bar{1}0$	5	110° 41′–111° 11′	110° 59′	111° 10′
$c:m=001:110$	2	83° 25′– 83° 30′	83° 30′	83° 30′
$c:r=100:\bar{1}12$	2	43° 13′– 43° 20′	43° 20′	43° 20′
$c:e=001:011$	7	54° 10′– 54° 52′	54° 45′	54° 45′
$e:e'=011:0\bar{1}1$	5	108° 59′–109° 23′	109° 23′	109° 30′
$r:r'=\bar{1}12:\bar{1}\bar{1}2$	2	69° 34′	69° 34′	69° 29′
$m:e=110:011$	4	42° 17′– 42° 25′	42° 25′	42° 21′
$e:r=011:\bar{1}12$	4	27° 22′– 27° 29′	27° 25′	27° 44′
$m:r=110:11\bar{2}$	2	53° 10′– 53° 22′	53° 10′	53° 10′

The accompanying figure (Fig. 4) shows the usual development of the crystals. This development was quite constant for all that were examined. Fig. 5 shows the same forms in horizontal projection on the plane of the clinopinacoid. Here is better shown, too, the relative greater length of the crystals in the direction of the clinodiagonal axis. The faces of the prism *m* (110) are usually duller in lustre than the others, and the basal plane *c* (001) is often striated parallel to the edge *c r*.

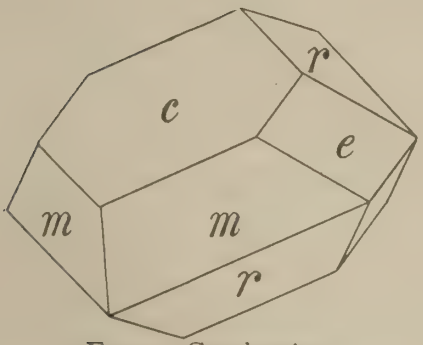


FIG. 4—Gay-lussite.

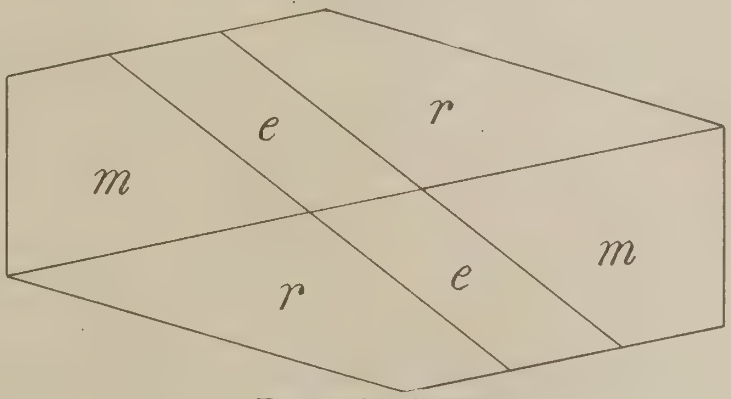


FIG. 5—Gay-lussite.

EPSOMITE.

NEAR WILCOX STATION, 65 MILES NORTH OF LARAMIE, WYOMING.
MUSEUM No. M 6126.

An account of the above occurrence of epsomite was given the writer by Prof. W. C. Knight of the University of Wyoming, in a recent letter. He writes: "A deposit of epsomite, which is of variable depth, covers an area of 90 acres near Wilcox Station, Albany County, Wyoming. In the spring the area is covered with water to the depth of a foot or more, forming a small lake, but on the advent of summer the water evaporates rapidly and an abundant deposit of beautifully crystallized epsomite is left."

A few of these crystals were received from Prof. Knight at the same time by the writer, but not being able to study them immediately, they became, through deliquescence, unfit for thorough crystallographic investigation. I have thought it desirable, however, to publish an account of the occurrence so that any who may visit the locality may improve the opportunity to secure material whose forms may admit of exact determination. The crystals received by the writer are from 8 to 15 mm. in length and are of elongated prismatic habit. Many are doubly terminated and have pyramidal planes which plainly show sphenoidal symmetry. The habit of the crystals and the fundamental forms are shown by Fig. 6. The determination of the pyramid z (111) depends on a measurement secured as follows:

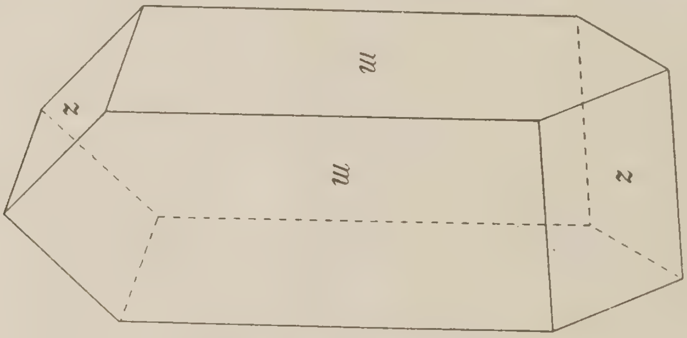


FIG. 6—Epsomite.

		Measured.	Calculated.
$m:z = 110:111$	=	50° 30′	50° 55′

While some of the crystals have only the simple development represented in the figure, others are evidently more highly modified, but owing to the deliquescence previously referred to, it was found impossible to determine the forms.

GOLDEN CALCITE.

BAD LANDS, SOUTH DAKOTA. MUSEUM No. M 5904.

On breaking open the concretions found in beds of Fort Pierre shale in the region of the Bad Lands, South Dakota, the internal cavities are often found to be studded with crystals of calcite of a more or less golden yellow color. While this occurrence of calcite has been known for some time, the form of the crystals has not heretofore received description. A large quantity of the crystals having been collected by the Museum Expedition to the Bad Lands of 1898, I have examined them with the following results: In form the crystals are all simple rhombohedrons having the symbol f, $-2R$. This symbol is sufficiently established by the relation of the cleavage rhombohedron to the crystal form and by several measurements ranging from 101° 25′ to 101° 35′ for $f : f = 02\bar{2}1 \wedge \bar{2}021$. The calculated value is 101° 9′. No planes could be found which were suited to accurate measurement, even the most favorable giving only dim and elongated reflections. The most interesting feature of the crystal form is the distortion which it exhibits. Although some of the crystals show a normal development of the rhombohedron, the greater number are lengthened out along an axis normal to one of the rhombohedral planes. The appearance is therefore that of a monoclinic crystal made up of a prism and basal planes. This apparent prismatic form is made more striking from the fact that the crystal usually rises more or less perpendicularly from its plane of attachment. The apparent basal plane is usually more or less curved, and has a somewhat pearly lustre. The prismatic planes are often curved as well. The length of the apparent prisms varies from a few millimeters to about 2 centimeters. The form of these crystals is represented in Fig. 7. Another form of distortion is shown in Fig. 8. Here the lengthening out has taken place in two directions, so that an apparently flattened rhombohedron results. The planes of such crystals show a curving

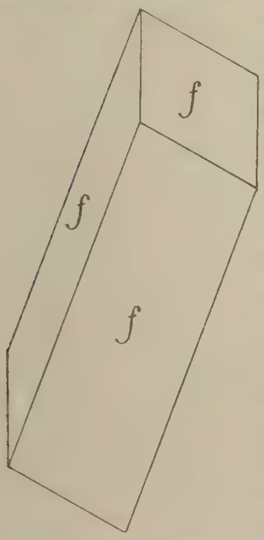


FIG. 7—Golden Calcite.

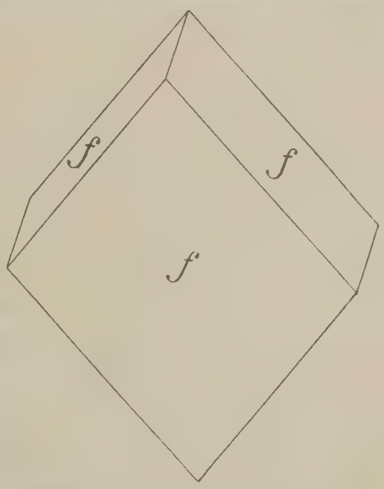


FIG. 8—Golden Calcite.

similar to those previously described. The color of the crystals of all types varies from a pale yellow to a deep orange. Some are perfectly transparent, but the majority are translucent to opaque. The yellow color is probably due to the presence of iron, as on heating the crystals turn black and become slightly magnetic. Other qualitative tests likewise indicate the presence of considerable iron.

DOLOMITE USED AS INDIAN MONEY.

NEAR LAKEPORT, LAKE COUNTY, CALIFORNIA. MUSEUM No. M 6387.

Specimens of dolomite from the above locality, and of the "money" made from it, were collected by Dr. G. A. Dorsey, Curator of Anthropology of the Museum, during a visit made in 1889 to the Pomo Indians, a tribe of the Kulanapan stock who inhabit the region. The material has long been used as a medium of exchange among these Indians, but I cannot learn that it has been hitherto described.

The mineral occurs in the form of nodules, or boulders, roughly oval in shape, and from four to eight inches in diameter. They are of a rusty yellow color upon the surface and the local Indian name for them, *Pol'-ka-be*, means rusty color. A freshly fractured surface shows a pure white color, except for occasional rusty seams, and lustre like that of unglazed porcelain. The texture is compact and fracture flat conchoidal. A determination of the specific gravity of a pure white fragment gave G. = 2.878. Dr. Dorsey did not visit the mine whence the dolomite is obtained, but was informed that it was situated on the east shore of Clear Lake, a few miles southeast of Lakeport.

While the mode of occurrence cannot be stated with certainty, it is probable that it is as residual boulders in a reddish clay.

A partial analysis by the writer gave CaO, 28.27%, MgO, 22.46%, and FeO, 1.18%. These percentages are nearly those of a typical dolomite.

The use of the mineral by the Indians as a medium of exchange is a long established custom, and the value at which they esteem a well worked piece is nearly equal to its weight in gold. In order to make the money, symmetrically shaped cylindrical pieces are cut out from the crude boulders. These are burned and the burning brings out reddish streaks of color doubtless from oxidation of the iron, which adds to the beauty of the pieces in the eye of the Indian. The pieces are then polished and perforated and pass as money, the local Indian name for them being *Po.* Many of the small pieces are also used as beads for necklaces and other ornaments. Fig. 9 shows the appearance of two typical pieces of *Po.*

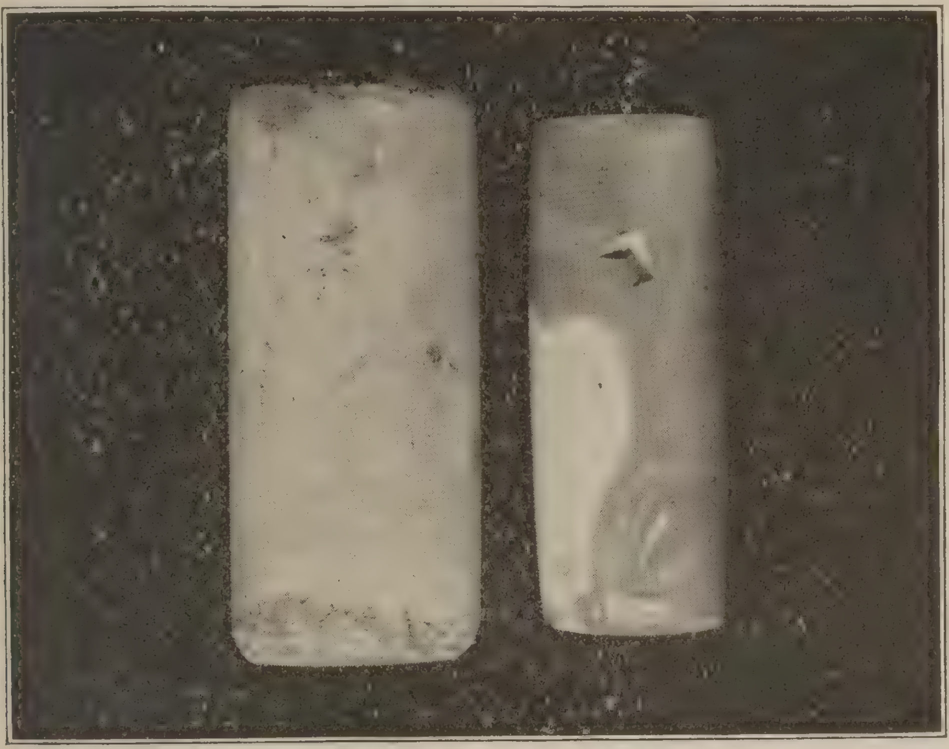


FIG. 9.

CRYSTAL FORMS OF CALCITE FROM JOPLIN, MISSOURI.

Large crystals of calcite from Joplin, Missouri, have been known for some years to collectors, and have become widely distributed in collections. The crystals are remarkable, not only for their size, but for their transparency, varied color and the perfection of their crystal form. So far as I can learn no crystallographic study of these calcites has ever been published. Photographs of some of the crystals, together with some general statements as to the occurrence of calcite in Missouri, are to be found on pp. 457–9 of Vol. VII, of the Reports of the Missouri Geological Survey. There is also mention, on p. 567 of the same volume, of calcite crystals of large size occurring in Crystal Cave, Joplin, and some description of the cave is given. No crystallographic details are given in this account, however, the crystals being simply described as scalenohedral or rhombohedral. The present study of some of the crystal forms can in no sense be considered a complete one, since the only material undertaken to be described is that comprised in the Museum collections, and some crystals that were kindly loaned for examination, through Prof. J. P. Iddings, by the University of Chicago. Having, however, cursorily examined a large number of crystals from this locality as exhibited in collections, both in this country and in Europe, I may say that I have found them to be remarkably uniform in character, and hence believe the characteristic forms to be largely comprised in the types here described. The specimens in the Museum collection have been obtained from various sources, chiefly by purchase or exchange, but some were collected at the mines in Joplin during the spring of 1898 by Mr. H. W. Nichols, Assistant Curator of Geology.

LOCALITIES OF LARGE CRYSTALS.

The large crystals known to collectors are chiefly of two types, differing in color and form. Those of the type which I may designate as Type No. 1 are characterized by a delicate violet to wine yellow color, often showing within a deeper yellow or violet light-

These came from the Blakie No. 2 mine. The crystals which may be designated as Type No. 2 are characterized by a deep amber yellow color ranging to colorless. They come from the Crystal Cave, Ino mine. These two mines are quite near one another, and are both located in Leadville Hollow, within the city limits of Joplin.

FORMS OF LARGE CRYSTALS.

TYPE 1.—Crystals of this type are very simple in form. They are made up of the common scalenohedron *v*, $+R3$,* truncated by the flatter scalenohedron *t*, $+\frac{1}{4}R3$. The average development of the forms is illustrated in Fig. 1, Pl. xxviii, it being drawn one-half size from one of the crystals in the Museum collection. Such a size is usual to crystals of this type. The following are averages of measurements of several angles on crystals of this type, as made with a contact goniometer:

		Measured.	Calculated.
$t:t'$	$=21\bar{3}4 : \bar{2}3\bar{1}4=$	42°	41° 55′
$t:t^{v}$	$=21\bar{3}4 : 3\bar{1}24=$	22°	20° 36½′
$t:v$	$=21\bar{3}4 : 21\bar{3}1=$	36°	35° 56′
t: cleavage	$=21\bar{3}4 : 10\bar{1}1=$	16°	16° 29′
$v:v'$	$=21\bar{3}1 : 3\bar{1}\bar{2}1=$	74°	75° 22′
$v:v^{v}$	$=21\bar{3}1 : \bar{2}3\bar{1}1=$	35°	35° 36′
v: cleavage	$=21\bar{3}1 : 10\bar{1}1=$	30°	29° 2′

The surfaces of the crystal planes on these crystals are, in general, flat and bright and of uniform lustre. They are, however, more or less irregularly marked similar to the planes shown in Fig. 2, Pl. xxviii, and reëntrant angles resulting from abortive terminations often occur. While the crystals are often doubly terminated, as illustrated in the figure, more commonly only about half of the complete crystal form is present, the plane of attachment being a rhombohedral or a basal plane. Numerous planes of rhombohedral cleavage pass through the crystals, and the light reflected from them often brilliantly illuminates the interior. Many crystals are also often iridescent from interference colors produced by parting along cleavage planes. Irregularly shaped grains of marcasite from one to two millimeters in diameter often occur scattered through the outer layers of the crystals. Other associated minerals, often well crystallized and found more or less in contact, are galena, dolomite and chalcopyrite. A group of this character, now in the Museum collection, is shown in the frontispiece.

---

*The letters used are Dana's.

TYPE 2.—Crystals of this type are characterized, as has been said, by an amber yellow color. This may be deeper or paler. The size of the crystals is also remarkable. Some are known 2½ feet (.76 meters) in length, and the average size of those seen in collections is from 6 inches (.15 meters) to 1 foot (.30 meters) in length. Those seen in collections are rarely, if ever, doubly terminated, only about half of the complete crystal being present. Some account of the mode of occurrence of these crystals in a cave as well as a plan of the cave is given, as already mentioned, on p. 567 of Vol. vii, Reports of the Missouri Geological Survey. For the following further information I am indebted to Mr. Henry Weyman, the present owner of the cave: "The cave is from 250 to 300 feet long, from 40 to 60 feet wide and of an unknown depth in places, *i. e.*, we have never been able to measure the bottom, as only a part of it is above water. The whole opening is covered with crystals of various sizes, leaving no place on any of the roof or wall exposed and going down as far as can be seen in the water. At one place a slab covered with large crystals has fallen from the roof at some time, and since then new crystals have formed on the roof where the slab has been broken away; also new crystals have formed on the broken side of the slab after it had fallen down. The largest crystals, I should think, would measure 2 to 2½ feet long. The greater part of the crystals are doubly terminated, ending in very sharp points. The cave was discovered by mining after lead and zinc ore, when a shot put in the bottom of the drift broke through the roof of the cave and so exposed the mass of beautiful crystals. This is so far the only opening allowing admittance to the cave. It is our intention to preserve the cave in its present state and make access to it more convenient to visitors." It is also stated in the account previously mentioned* that the cave is remarkable for the entire absence of stalactites of the usual type. Since these are absent it is probable that the cave at the time of formation of the crystals was filled with water holding carbonate of lime in solution, from which crystallization took place. Had the cave been only in part filled with water, the dripping waters would doubtless have formed stalactites of the usual type.

The form of the crystals of Type 2 is primarily determined by the common scalenohedron v, $+ R3$. This may alone constitute the crystal or its form may be slightly or highly modified. A common modification is the truncation of the apex of the scalenohedron by the rhombohedron e, $-\frac{1}{2} R$. Fig. 2, Pl. xxviii, represents a combination

---

*Report of the Missouri Survey *loc. cit.*

EXPLANATION OF PLATE XXVIII.

FIG. 1. Crystal of Type 1.
Joplin Calcite.
One-half natural size.
Mus. No. M5513.

FIG. 2. Crystal of Type 2.
Joplin Calcite.
One-half natural size.
Mus. No. M5621.

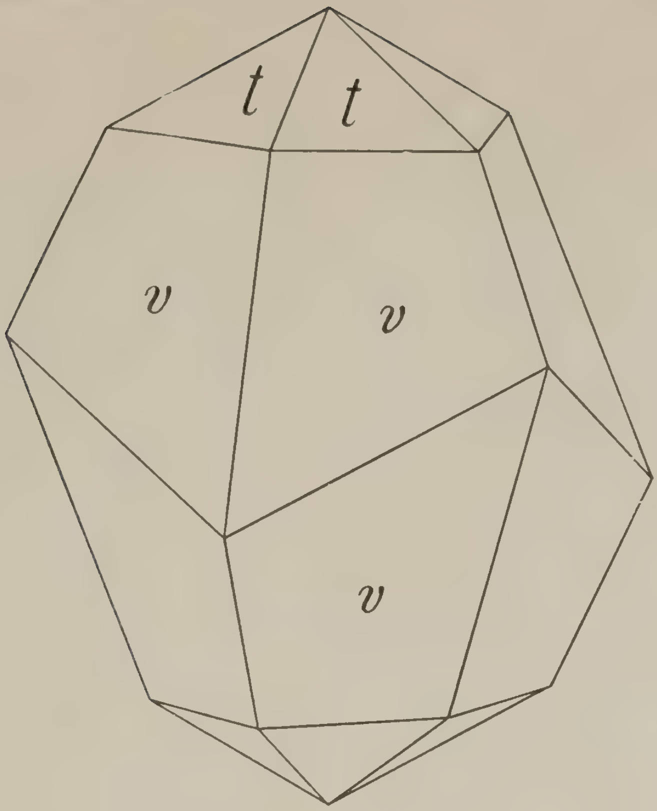


FIG. 1

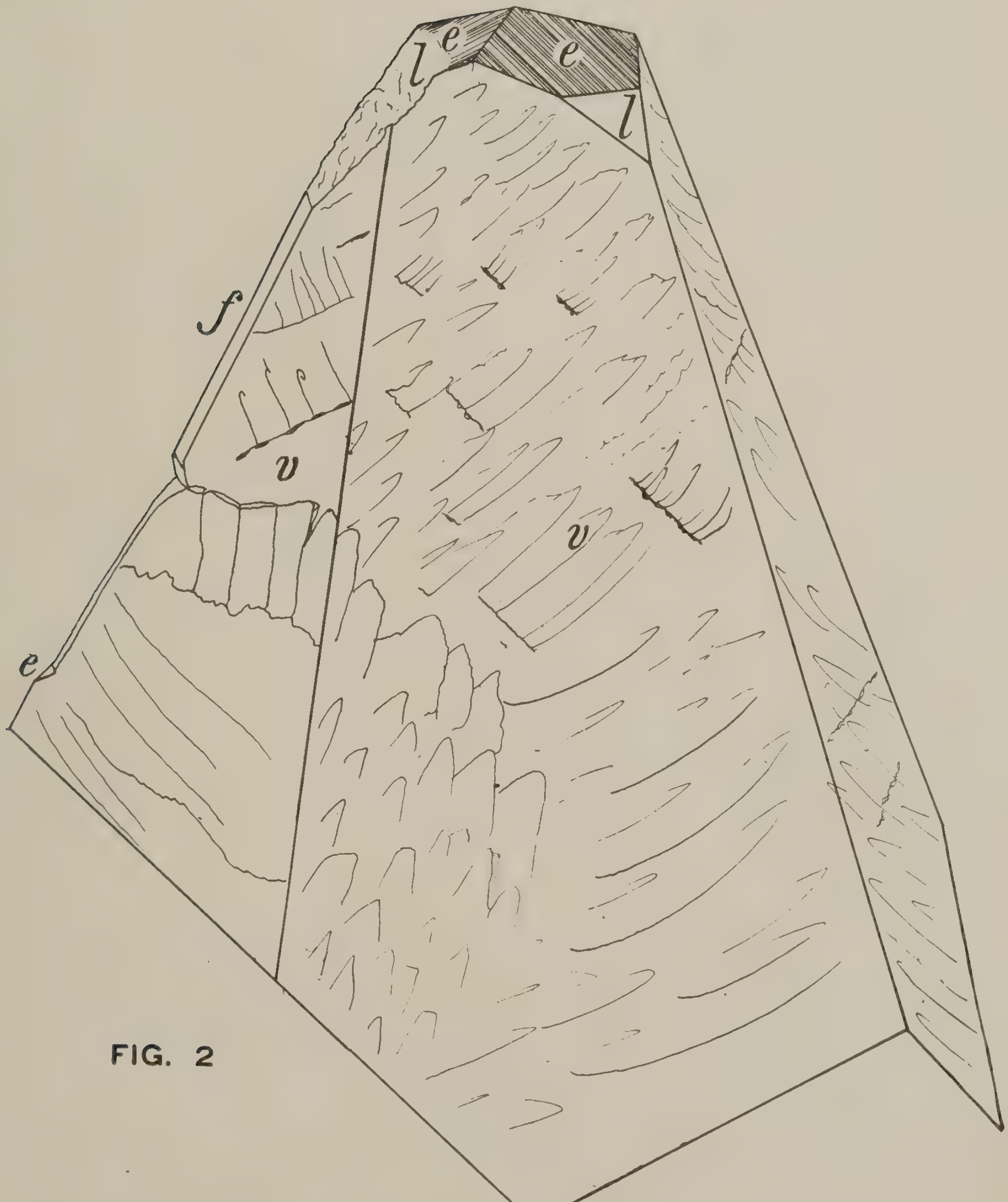


FIG. 2

CALCITE, JOPLIN, MO.

LIBRARY
OF THE
UNIVERSITY of ILLINOIS.

of these forms together with the rhombohedron *l*, $-\frac{4}{5}$ R, as seen on a crystal in the Museum collection. There is also present one plane of the negative rhombohedron *f*,−2R.

Some measurements made on this crystal with the contact goniometer are as follows:

	Measured.	Calculated.
$v : l = 21\bar{3}1 : 04\bar{4}5 =$	43°–44′	44° 6′
$v : f = 21\bar{3}1 : 02\bar{2}1 =$	35°–38′	37° 41′
$e : l = 01\bar{1}2 : 04\bar{4}5 =$	11°–12°	12° 2′
$e : v = 01\bar{1}2 : 21\bar{3}1 =$	45°–52°	50° 36′

As has often been observed on calcites from other localities, the planes of the rhombohedron *e*,−½ R are, in this crystal, striated parallel to the edge *r*/*r*′. They are also somewhat rounded. The curious sporadic occurrence of the plane *f* and the accompanying imperfect growth of planes seems to be quite common for Joplin crystals showing the above combinations. At least the writer has noticed the same appearance on several other similar but smaller crystals. It would be interesting to know the nature of the molecular forces which would uniformly produce degradation of this sort. The planes of the scalenohedron *v* on the crystal are in general flat and bright, but show peculiar markings suggesting stages of growth. These markings are quite irregular in form and seem to have no angular values whatever. They follow, however, so far as they have any arrangement, the lines of the cleavage rhombohedron. Partings along planes of this rhombohedron are to be seen through the crystal and the surface of attachment is usually characterized by cleavage planes.

Other crystals of Type 2 are more highly modified than the one just described. Fig. 1, Pl. xxix, represents one such crystal now in the Museum collection. Here the primary scalenohedron *v*, + R3 is modified by the scalenohedrons *n*, + $R\frac{5}{3}$ and *w*, + $\frac{2}{5}$ R2, also by the positive rhombohedrons *r*, + R and *M*, +4R, and by the negative rhombohedron *l*,$-\frac{4}{5}$R. Only about half the complete form is present in the specimen. In Fig. 2, Pl. xxix, is shown the completed ideal form which would be produced by these combinations. Some of the measurements made on this crystal with the contact goniometer are as follows:

	Measured.	Calculated.
$v : r = 21\bar{3}1 : 10\bar{1}1 =$	30°	29° 2′
$v : M = 21\bar{3}1 : 40\bar{4}1 =$	18°	19° 24′
$r : M = 10\bar{1}1 : 40\bar{4}1 =$	31°	31° 10½′
$v : l = 21\bar{3}1 : 04\bar{4}5 =$	44°	44° 6′

	Measured.	Calculated.
$r : l = 10\bar{1}1 : 04\bar{4}5 =$	40°	39° 4′
$l : l' = 04\bar{4}5 : \bar{4}045 =$	65°	64° 53½′
$v : n = 2\bar{1}31 : 41\bar{5}3 =$	17°	14° 28½′
$n : n' = 41\bar{5}3 : \bar{4}5\bar{1}3 =$	78°	78° 5′
$n : n^{v} = 41\bar{5}3 : 5\bar{1}\bar{4}3 =$	19°	18° 7′
$v : w = 21\bar{3}1 : 31\bar{4}5 =$	33°	33° 50′
$w : w' = 31\bar{4}5 : 4\bar{1}\bar{3}5 =$	50°	49° 23′
$w : w^{v} = 31\bar{4}5 : 5\bar{1}\bar{4}3 =$	16°	16°

The planes of *r* are further identified by their evident parallelism to the cleavage planes.

An interesting peculiarity of the specimen is the surface differentiation of the planes. Thus the planes of the scalenohedron *v* and the negative rhombohedron *l* are flat and bright ; those of the scalenohedrons *n* and *w* are striated parallel to the adjoining edges of the unit rhombohedron, and the planes of the unit rhombohedron and the rhombohedron *M* are rough. The differentiation closely follows and beautifully illustrates the law that crystallographically equivalent planes are similarly affected. An examination of the rough planes reveals but little in the way of symmetrical etching figures. The roughness is caused chiefly by delicate pitting, which is also wholly irregular. There are to be seen occasional pits, however, which are larger than the others and which have a definite pyramidal shape. They are different in form from the etching figures usually produced artificially on calcite by hydrochloric acid. The boundaries of the pits lie parallel to the bounding planes of the unit rhombohedron. Their character is illustrated in the accompanying figure (Fig. 10).

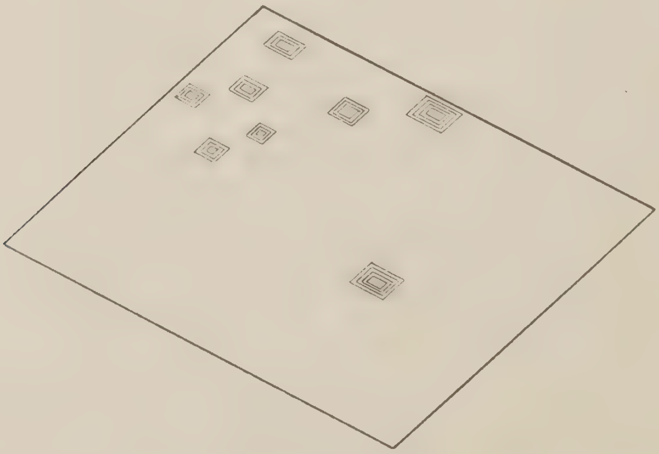


FIG. 10—Growth figures on plane of +R. Calcite, Joplin, Mo.

EXPLANATION OF PLATE XXX.

FIG. 1.	Basal twin of Joplin Calcite. One-half natural size. University of Chicago collection.	FIG. 2.	Ideal form of twin shown in Fig. 1.

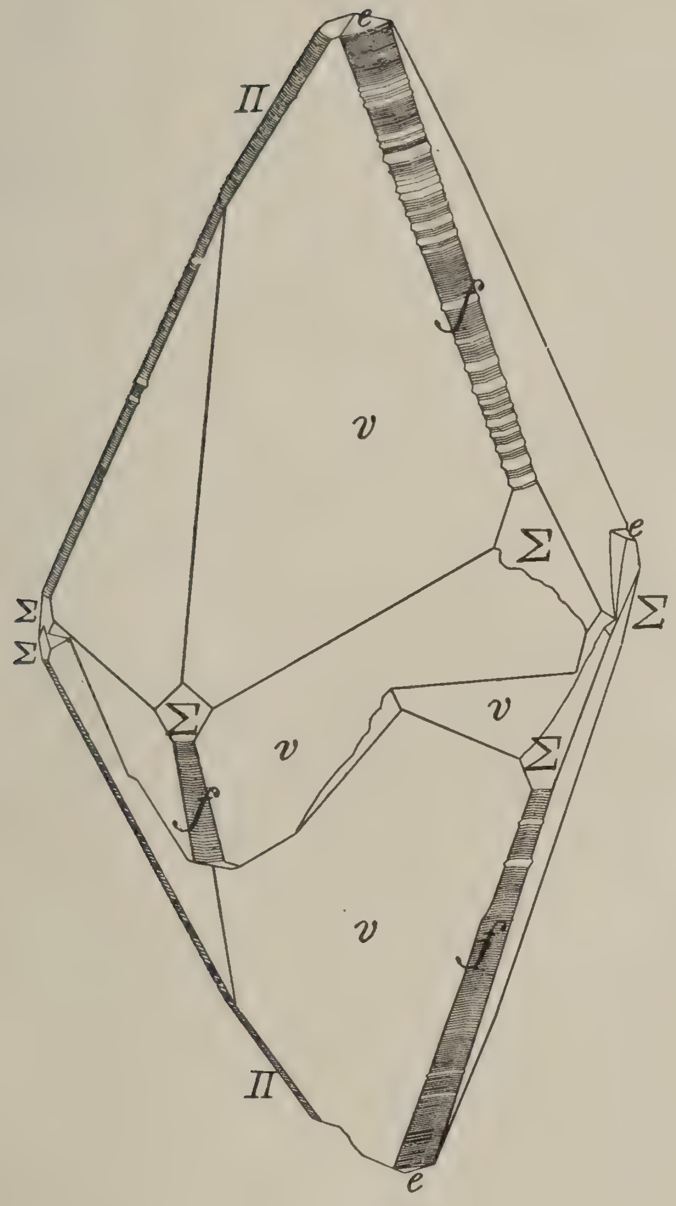


FIG. 1

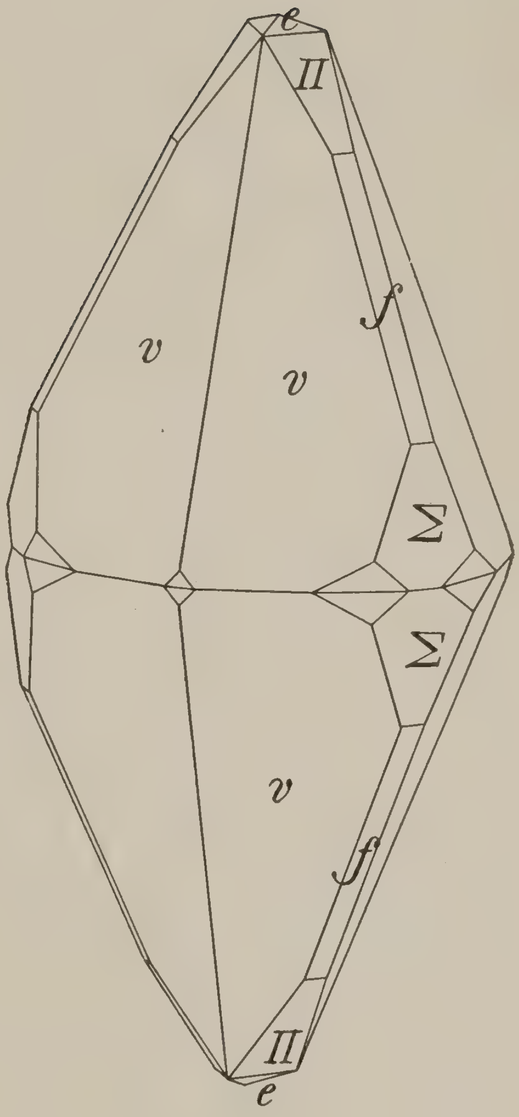


FIG. 2

Calcite, Joplin, Mo.

LIBRARY
OF THE
UNIVERSITY of ILLINOIS.

FORMS OF SMALLER CRYSTALS.

None of the following crystals have the large size of those of the types above described. They show, however, characteristic combinations which warrant their description as types.

Type 3.—Crystals of this type are illustrated in Fig. 3, Pl. xxix. As is usual with the Joplin crystals they are not highly modified, being made up solely of the scalenohedrons v, $+R3$ and w, $\frac{2}{5}R2$. The specimens of these crystals in the Museum collection come from the Pelican mine in Joplin, occurring with sphalerite on the characteristic chert breccia of the region. A large group is shown in the frontispiece. The largest single crystal is not over 4 inches (10 cm.) in length, and from this the crystals grade to a very small size. Measurements of the planes made with the reflecting goniometer are as follows:

	Measured.	Calculated.
$v : v' = 21\bar{3}1 : \bar{2}311 =$	75° 25′	75° 22′
$v : v^{\text{v}} = 21\bar{3}1 : \bar{3}121 =$	35° 36′	35° 36′
$v : v^{\text{vi}} = 3\bar{1}\bar{2}1 : 3\bar{2}\bar{1}1 =$	46° 53′	47° 1½′
$w : w' = 31\bar{4}5 : \bar{3}4\bar{1}5 =$	50° 58′	49° 23′
$w : w^{\text{v}} = 31\bar{4}5 : 4\bar{1}\bar{3}5 =$	15° 59′	16°

The most striking characteristic of these crystals is the fact, represented in the figure, that the planes of scalenohedron v are smooth and brilliant, while those of w are rough. This differentiation of planes is constant for all the crystals which have come under the writer's observation. The rough planes do not show definite etching figures, but rather under a lens series of troughs crossing one another and following the lines of the cleavage rhombohedron. In the writer's opinion the roughness is due to irregularities of growth of the crystals rather than to etching. The reasons for this opinion are: First, it is difficult to conceive of any etching agent which could leave the planes of one scalenohedron so entirely untouched while those of the other were so deeply corroded. Second, on submitting the crystal to the action of weak vinegar as an etching agent the planes of the scalenohedron v were affected much more rapidly and noticeably than those of w. The etching produced by the vinegar on the planes of v was in the forms of troughs or striæ following the lines of cleavage, on w there occurred only a slight additional roughening of the planes. It is, therefore, in the writer's opinion, not always correct to speak, as is usually done, of the rough planes as *etched* planes. They will often be more correctly described by the term *imperfect* or *incomplete* planes.

TYPE 4.—The only crystals of this type in the Museum collection come from Leddy's Lease, Central City, about 5 miles from Joplin. They are, however, a characteristic type for the Joplin district. They are scalenohedral in character, often doubly terminated, colorless, and frequently reach a length of from 2 to 3 inches (5–7.5 cm.). The forms characterizing the type are v, $+R3$ dominant with $e, -\frac{1}{2}R$, $f, -2R$ and $\Sigma, -11R$, subordinate. A characteristic feature is the habitually rounded and cross striated character of the planes of f. In fact this form often grades into a scalenohedron of large indices, the symbols of which it is impossible to determine. The planes of f likewise usually widen toward the apices of the crystal, so as to crowd out the planes of v, and themselves define the termination of the crystal. Fig. 1, Pl. xxx, sufficiently illustrates the average development of planes on crystals of this type, although the one figured is a twin crystal and larger than the average of the type.

TYPE 5.—Crystals of this type are of rhombohedral development. Type specimens in the Museum collection come from the Meadowcroft mine, Joplin. They are colorless, and not over 1 inch (2.5 cm.) in length. They are made up of the negative rhombohedrons $\eta, -4R$ and $f, -2R$ dominant, with the latter truncated by $e, -\frac{1}{2}R$. A typical crystal is shown in Fig. 4, Pl. xxix. The planes of f and η are considerably curved, and admit of only approximate measurement. The symbol of f was, however, sufficiently determined by its relation to the cleavage rhombohedron, and that of η was determined from the mean of measurements of ten crystals, which gave $e : \eta = 02\bar{2}1 : 04\bar{4}1 = 49°$. The calculated value is 49° 32′. The planes of e are usually smooth and bright, those of f are deeply striated parallel to the edge $f\eta$, and those of η parallel to the longest diagonal of the rhomb. Rounding of the planes of the three rhombohedrons e, f and η into one another is common. One crystal showed an intermediate rhombohedron between e and f, but it was impossible to obtain a measurement sufficiently satisfactory to determine its symbol. In some crystals again the rhombohedron f is absent and the crystal is made up of only the forms $\eta, -4R$ and $e, -\frac{1}{2}R$.

FORMS OF TWINNED CRYSTALS.

Only a few twinned crystals were noted among those examined. The larger number of those noted are twinned upon the basal plane. These occur of both Types 3 and 4. The crystal chosen for special study was of Type 4, and is from the collection of the University of

EXPLANATION OF PLATE XXIX.

FIG. 1. Crystal of Type 2.
Joplin Calcite.
One-half natural size.
Mus. No. M5515.

FIG. 2. Completed ideal form of crystal shown in Fig. 1.

FIG. 3. Crystal of Type 3.
Joplin Calcite.
Mus. No. M5511.

FIG. 4. Crystal of Type 5.
Joplin Calcite.
Mus. No. M5824.

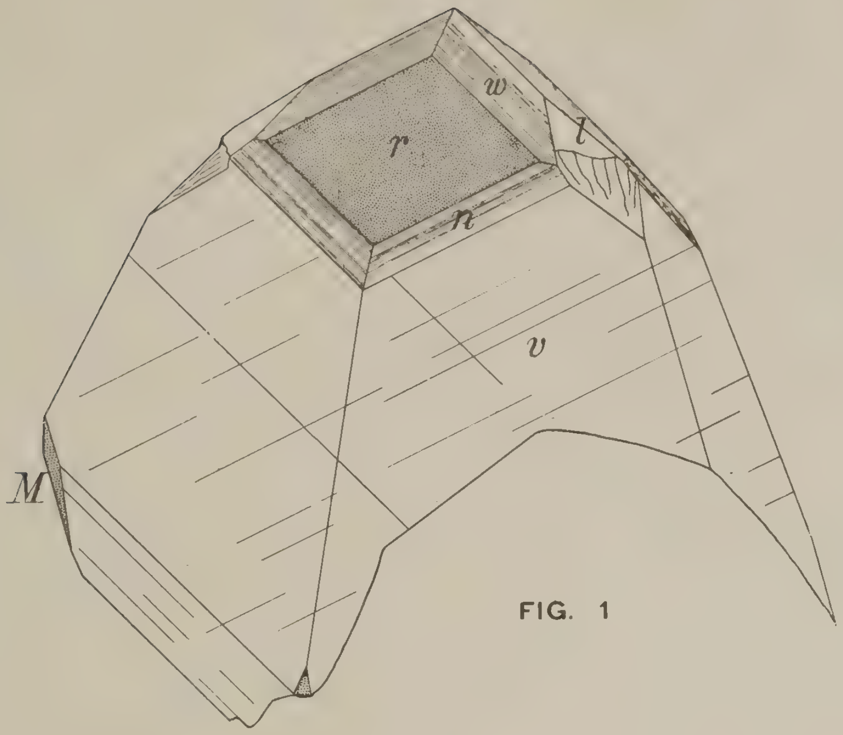


FIG. 1

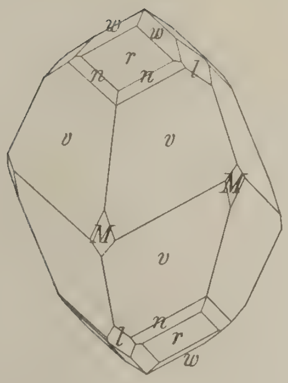


FIG. 2

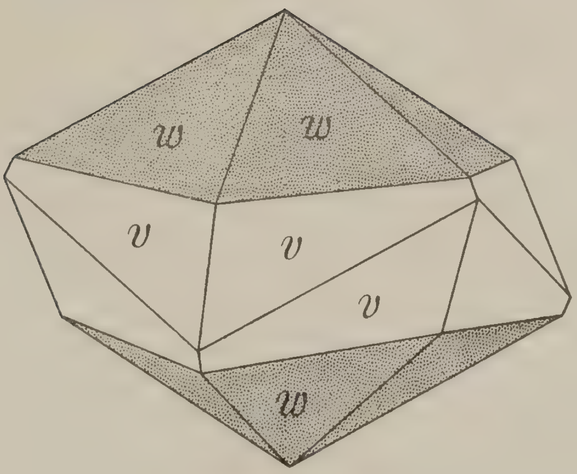


FIG. 3

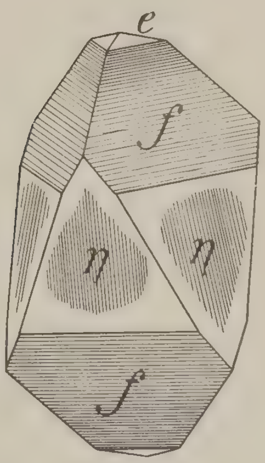


FIG. 4

Calcite, Joplin, Mo.

LIBRARY
OF THE
UNIVERSITY of ILLINOIS.

Chicago. The crystal is shown in Fig. 1, Pl. xxx. Measurements made in the zone of the negative rhombohedrons on this crystal with the contact goniometer are as follows:

	Measured.	Calculated.
$e : \Pi = 0\bar{1}12 : 0\bar{7}75$ =	28°	27° 51′
$\Pi : f = 0\bar{7}75 : 0\bar{2}21$ =	9°	9° 1′
$e : f = 0\bar{1}12 : 0\bar{2}21$ =	36°	36° 52′
$e : \Sigma = 0\bar{1}12 : 0.11.\overline{11}.1$ =	59½°	58° 29′

The determination of Σ rests rather on its occurrence on other crystals of this type which could be measured with a reflecting goniometer, than on the value obtained on this crystal, it being presumed that the same plane was most likely to occur again.

The peculiar distortions and striations exhibited in this crystal are illustrated in the figure. How far these have caused it to depart from the normal form may be seen by comparing Figs. 1 and 2, Pl. xxx. The tendency shown in this crystal for the two individuals of the twin to grow by one another and partially complete themselves, is quite common among the Joplin twins. Further struggles of the molecular forces are illustrated by the number of abortive planes of *e*, −½R, these being so numerous as to produce cross striations on *f*, −2R. The latter planes are further rounded from the tendency to produce scalenohedral forms.

Another and the only other type of twin crystal noted has *e*, −½R as the twinning plane. Such twins occur among a group of calcite crystals formed together on a specimen in the collection of the University of Chicago. The crystals of this group are in general scalenohedral in form, colorless to amber in color, and vary from 1 to 2 inches (.3 to .6 cm.) in length. Many are simple crystals made up of *v*, +R3 dominant, modified by *e*, −½R, *f*, −2R, and a form new to calcite, *Ω*, −20R.* Others are intermediate in character, and are the result, doubtless, of one individual pushing by the other, as twins on the base have already been shown to do. Such a crystal is represented in Fig. 1, Pl. xxxi, the crystal being drawn in the position of the negative scalenohedron in order better to show the elongation in one direction. This elongation characterizes the true twins as well. In this crystal on the side toward the observer, although the lower part of the crystal is quite incomplete, the boundary planes are evidently those of a twin crystal. On the reverse side, however, the development is that of a simple crystal.

---

*The letter given to this form was chosen in accordance with Goldschmidt's system, Dr. Charles Palache having kindly indicated to me what the appropriate letter, according to this system, would be. I do not feel called upon to apologize for thus combining Dana's and Goldschmidt's lettering. I deem it essential that new forms should be lettered in accordance with Goldschmidt's system in order to avoid conflict of letters, but the common forms are, and are long likely to be, better known by Dana's letters.

The completely formed twins resemble in many respects those from Guanajuato, described by Pirsson.* The twinning plane is the same, the lengthening out in one direction is similar, though not to the extent of the Guanajuato crystals, and the proportional development of the faces is analogous. The Joplin twins, however, differ notably from those of Guanajuato in their development at the apex of the salient angle. In the Guanajuato twins the scalenohedral planes of the two individuals of the twin are prolonged at the apex of the salient angle until they meet in a point. In the Joplin twins, however, the scalenohedral planes of each individual have only a normal development, and there is no prolongation to an apex. Some crystals occur in which one individual has grown by the other at the salient angle in the direction of the vertical axis of the individual, this being but another illustration of the curious tendency which has been previously noted. There is, however, no prolongation at the end of the twinning plane. The Guanajuato twins are usually attached at the salient angle, while the reverse is true of the Joplin twins. The attachment of the Joplin twins by the reëntrant angle often takes place at the end of a projecting process of calcite, usually more or less bounded by crystal planes, and seeming to serve as a sort of stem of crystal growth.

As regards the size of the twin crystals, it may be said that the longest noted measures 3 inches (.75 cm.) from end to end of the vertical axes. The lengthening out of the same crystal makes it about 1 inch (.25 cm.) long in the same direction. The combination of forms which make up these crystals has already been indicated. The determination of the new form Ω', $-20R$, rests upon its evident location in the two zones $v\,v'$ and $e\,m$ and upon a very accurate measurement with the contact goniometer of the angle $e : \Omega' = 0221 : 0.20.\bar{2}0.1 = 24°$. The calculated value is 23° 59′. The form usually has rounded planes. The determination of the other forms likewise rests upon measurements made with the contact goniometer, but these correspond so closely with calculated values, and the analogy of the occurrence of the forms is so similar to that of the other Joplin calcites that there can be little doubt of their being correctly identified. The form Ω, $-\frac{7}{5}R$, is quite sporadic in its occur-

---

*Amer. Jour. Sci. 3d Ser., Vol. 41, p. 61.

EXPLANATION OF PLATE XXXI.

FIG. 1. Partially twinned crystal of Joplin Calcite.
University of Chicago collection.

FIG. 2. Twin crystal of Joplin Calcite.
Twinning plane e, $-\frac{1}{2}$ R.
University of Chicago collection.

FIG. 3. Same crystal as Fig. 2, drawn in the position of the negative scalenohedron.

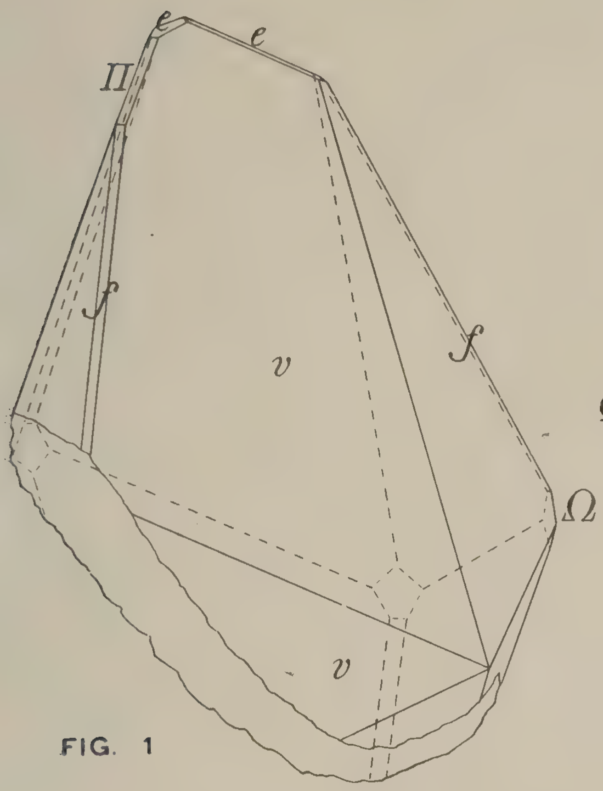


FIG. 1

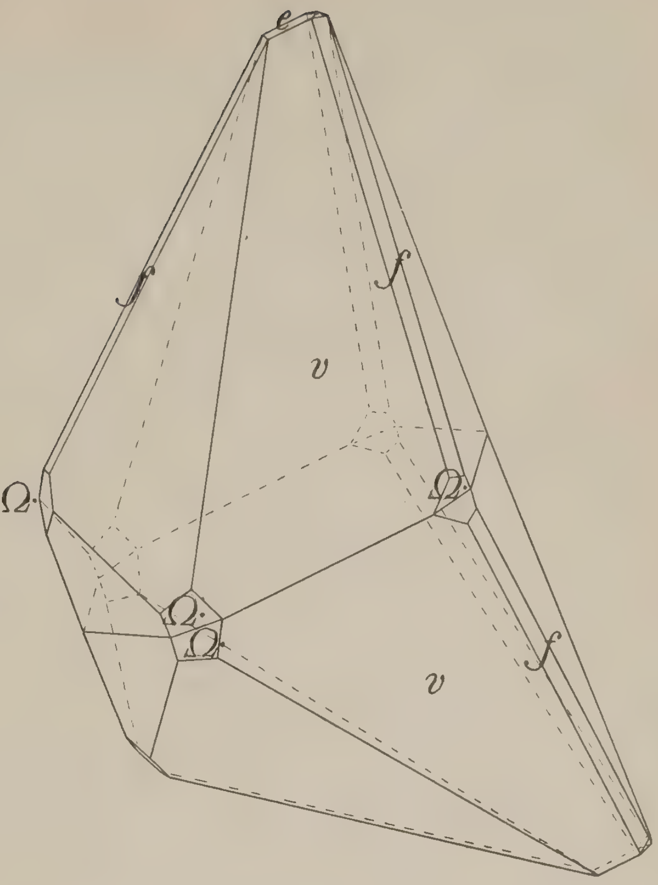


FIG. 2

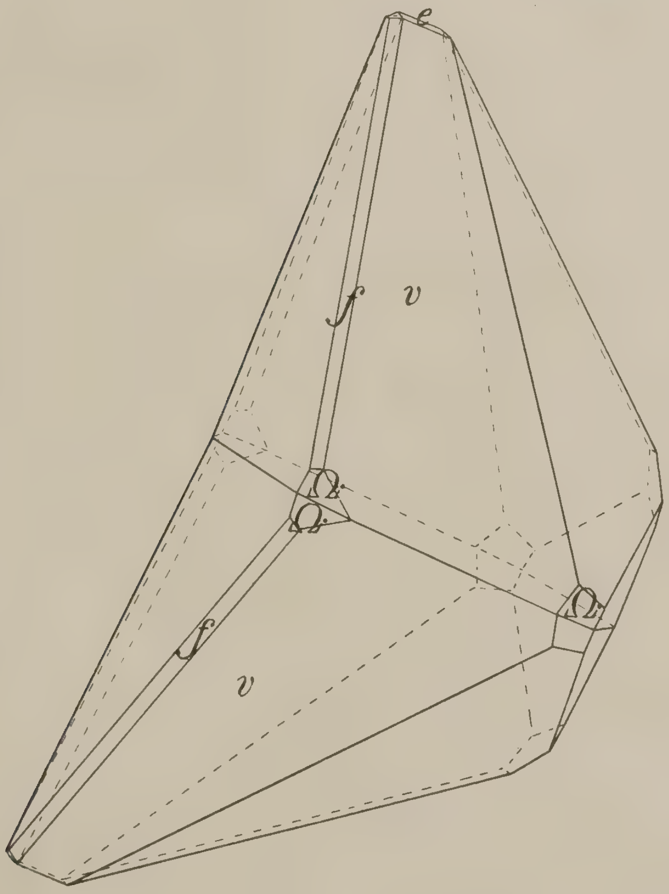


FIG. 3

CALCITE, JOPLIN, MO.

rence, appearing sometimes as a single plane, more often as two, and only once in its full number of three planes.

In conclusion, the following list includes the forms noted on the Joplin calcites by the writer:

r, $10\bar{1}1$, $+R$	n, 4153, $1\frac{5}{3}$	$+R_{\frac{5}{3}}$
M, $4\bar{0}41$, $+4R$	v, $21\bar{3}1$, 1^3	$+R3$
	w, $3\bar{1}45$, $\frac{2}{5}^{2}$	
e, $01\bar{1}2$ $-\frac{1}{2}R$	t, $21\bar{3}4$, $\frac{1}{4}^{3}$	$+\frac{2}{5}R2$
l, $04\bar{4}5$ $-\frac{4}{6}R$		
Π, $07\bar{7}5$ $-\frac{7}{5}R$		$+\frac{1}{4}R3$
f, $02\bar{2}1$ $-2R$		
η, $04\bar{4}1$ $-4R$		
Σ, $0.11.\overline{11}.1$, $-11R$		
Ω, $1.20.\overline{20}.1$, $-20R$		

It is evident that the largest variety of forms occurs in the zone of negative rhombohedrons. Indeed, it is hardly likely that the above list includes all the negative rhombohedrons which occur, as several measurements made by the writer indicated others, although they could not positively be identified. The positive rhombohedrons are of rare occurrence and have little to do with determining the forms of the crystals. Among the scalenohedrons, v, $+$ R3, is almost universally present and is usually the dominating form. This scalenohedron in connection with e, $-\frac{1}{2}$ R, and f, -2R, determines the habit of most of the Joplin crystals.

FIELD COLUMBIAN MUSEUM
PUBLICATION 53.
GEOLOGICAL SERIES. VOL. I, NO. 8.

OBSERVATIONS ON INDIANA CAVES.

BY

OLIVER CUMMINGS FARRINGTON, PH.D.,
Curator, Department of Geology.

CHICAGO, U. S. A.
February, 1901.

TABLE OF CONTENTS.

Page

Observations on Indiana Caves, - - - - - - 247

Wyandotte Cave, - - - - - - - 247

Marengo Cave, - - - - - - - - 256

Shiloh Cave, - - - - - - - - 262

Coan's Cave, - - - - - - - - 264

OBSERVATIONS ON INDIANA CAVES.

A visit of the writer to several caves in Indiana during the months of August and September, 1900, afforded an opportunity for a number of observations which seem to be new or confirmatory of observations previously published by others. The caves visited were Wyandotte Cave, Crawford County; Marengo Cave, Crawford County; Shiloh Cave, Lawrence County; and Coan's Cave, Monroe County, all in the State of Indiana. Detailed descriptions of all these caves have been given in several reports of the Geological Survey of Indiana, the latest and most complete being in the twenty-first annual report, 1896, by W. S. Blatchley. There is also given in that report a bibliography of the caves and their fauna.

WYANDOTTE CAVE.

Circular or Dome-shaped Halls.—The hall known as "Helen's Dome" has to a marked degree the form of a hollow cylinder standing vertically. "Rothrock's Cathedral" has the form of a huge dome roofing a short cylinder, the center of the dome being in turn cut by a cylinder rising above it. The "Senate Chamber" has a similar form except that its shape is elliptical rather than circular. "Odd Fellows' Hall," "Milroy's Temple," the "Hall of Representatives," and others are likewise dome-shaped. The hall known as "The Rotunda" in Mammoth Cave has also the form of a dome roofing a short cylinder. The dimensions of some of the halls as given by Blatchley* are as follows: Helen's Dome, 80 feet high and 20 feet in diameter; Rothrock's Cathedral, 185 feet high and 200 feet in diameter; the Senate Chamber, 60 feet high with elliptical axes 144 feet and 56 feet in length. The circular or elliptical contour of the walls of these halls and the persistence with which it is maintained throughout successive downfalls of rock is remarkable and indicates that some cause additional to ordinary water erosion must be sought.

**Op. cit.*

Water flowing down vertical joint planes usually produces pits with walls of angular contour, of which the "Bottomless Pit" in Mammoth Cave may serve as a type. It is possible that the circular contours may arise from a solvent action added in an unusual degree to the erosive action of water. By this means the solid angles of the limestone blocks formed by the junction of several vertical with one horizontal joint plane might be dissolved away until a dome-shaped cavity was formed, or the form may be due to a concretionary structure of the limestone like that recently noted in Idaho.* The consecutive removal of the centers of successive domes would cause each to fall in turn, maintaining the dome-like shape. Stream erosion on the floor of such halls may remove this rocky debris as fast as it falls as has been the case at Helen's Dome, or the rise of the conical pile of rocky debris (such as that known as "Monument Mountain" in Rothrock's Cathedral), may nearly keep pace with the fall of the domes above. It is evident that if this process of caving in is continued until the surface is reached, "cistern-like pits leading down into the bowels of the earth" will be seen from above. Such is the description given by W. H. Holmes† of the cenotes or sacred wells seen in Yucatan, some of which are so round and even-walled as to be taken for works of art. They are often, Holmes states, 100 feet or more in depth and 200 or 300 feet in diameter. It seems evident from what has been stated above that human agencies need not be appealed to for the formation of such wells.

FISSURE SYSTEMS.—Systems of fissures forming rectangles or parallelograms closely resembling those produced by Daubrée's well-known experiment illustrating the formation of joints by torsion are to be seen at many places along the roof of the cave. As an exhibition of jointed structure on a horizontal plane they are very satisfactory. Often a secondary system of fissures appears in conjunction with the primary one. In many places, such as the "Pillared Palace," the formation of stalactites and stalagmites has taken place along the lines of the joint planes. The stalactites and stalagmites extend, therefore, in straight lines in most cases directly beneath the crevice made by the joint plane.

DISTRIBUTION OF BATS.—Bats were found in all parts of the cave which I entered, even in the so-called "Unexplored Regions," the entrance to which is a passage averaging about one foot in height for a distance of 60 feet. If the bats were especially numerous anywhere, it was in the hall known as the "Senate Chamber," which, according to Blatchley's measurements, is one and one-sixth miles from the entrance to the cave. I may also remark that I noticed a similar wideness of distribution of the bats in Coan's Cave, though that is only one-eighth of a mile in length. These observations seem to contradict the statement of Mr. William H. Hess,* that "bats as a rule go but a short distance from the entrance," and throw doubt on any theory of the origin of nitrates in cave earths which rests on the assumption that bats do not inhabit the more remote portions of caves.

---

*A curious mineral formation in Idaho Engineering and Mining Journal, March 2, 1901.

†Field Columbian Museum Publication 8, p. 19.

VERMIFORM STALACTITES.—The vermiform stalactites which are to be seen in many places in this cave have attracted the attention of many observers and brought forth many theories as to their origin. These theories are admirably summed up and the subject ably treated in the paper by Merrill "On the formation of stalactites and gypsum incrustations in caves."† My observations lead me substantially to agree with Merrill's conclusion that the vermiform character of stalactites of this cave is due to the fact that the drops of water making them have been guided to other positions than those dictated by gravity by the directions assumed by spicules of calcite in crystallizing. It appears to me, however, that the carbonate of lime producing this effect must be in a condition differing somewhat from the ordinary pulverulent form in which it appears at the end of the usual stalactite tube, or in other words, that some additional conditions must be appealed to in order to lead to the formation of stalactites of this sort.

The resemblance of the stalactites to the well-known forms of aragonite denominated *flos ferri* is quite striking, and perhaps of some significance. Senft‡ reached the conclusion that the *flos ferri* forms of aragonite were produced from very dilute solutions of carbonate of lime, which, owing to protection from changes of air and temperature, evaporated very slowly. Calling attention to the form of the spicules of aragonite he deduced much the same theory for the origin of the *flos ferri* forms as that suggested by Merrill for the Wyandotte Cave vermiform stalactites. It is characteristic of aragonite, however, to crystallize in slender needles, but not so of calcite. Tests which I have made of the specific gravity of the substance of the Wyandotte vermiform stalactites indicates that it is, as originally regarded by Merrill, calcite. The exact stages of the process by which vermiform stalactites of calcite would be produced seem to me, therefore, less evident than are those by which such stalactites of aragonite are formed. Yet, until we have better knowledge it may be a reasonable hypothesis to suppose that the same conditions which produce such forms in aragonite (supposing Senft to have correctly judged those conditions) viz.: deposition from dilute solutions in sheltered situations, may be regarded as those which would produce similar forms of calcite. Why, however, aragonite should be produced in one case and calcite in the other, I can-

---

*Journal of Geology, Vol. 8, No. 2.

†Proc. U. S. Nat. Mus., Vol. XVII, pp. 77–81.

‡Die Wanderungen und Wandelungen des kohlensaures Kalkes, Zeitschrift der Deutsche Geologische Gesellschaft, Vol. XIII, p. 269.

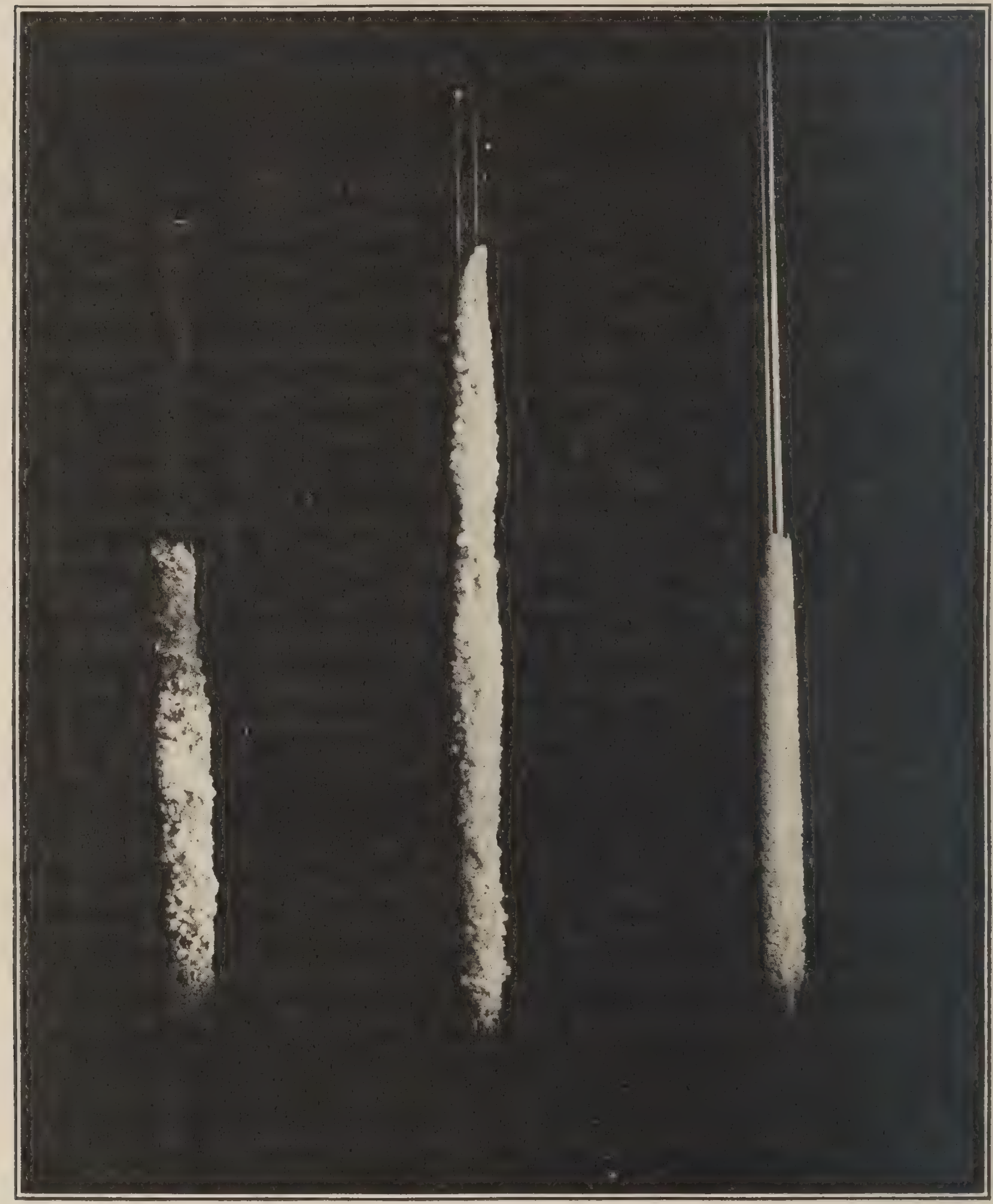


FIG. 1—Deposits produced by capillary attraction, on a stalactite, a glass rod and a glass tube.

not say, while further it may be noted that Foote's* experiments led him to conclude that rapidity of crystallization causes the formation of aragonite rather than the slow crystallization which Senft has postulated.

DEPOSITS PRODUCED BY CAPILLARY ATTRACTION.—The force of capillary attraction cited by Merrill as producing the vermiform stalactites is probably instrumental in modifying the forms of stalactites in general in a way to which attention does not seem to have been called before. In fact, it is probable that deposition from this cause takes place on a much larger scale than has hitherto been supposed. The nature of such deposits can be instructively determined experimentally. As deposition of carbonate of lime from solutions would take place too slowly for convenient study, I have used solutions of salt for this purpose.

Fig. 1 shows a deposit of salt formed by capillary attraction on a slender stalactite, a glass rod and a glass tube respectively. These deposits were obtained by supporting the several objects on end in a solution of salt to a depth of about one-fourth of an inch (6 mm.) for a week. The deposit on the stalactite, it will be noted, gathered about numerous centers giving a stippled appearance like that often seen on stalactites and illustrated by the figure of the stalactite shown in Fig. 2. This is in accordance with the well-known tendency of crystals to form secondary and tertiary branches. It is to be noted so far as the deposit on the glass tube is concerned that none formed inside the tube. Hence the stopping up of stalactite tubes cannot be ascribed to this cause. Attention may also be called to the large amount of deposit both on the tube and the rod, as indicating how considerable a deposit on stalactites may result from capillary attraction. In Nature it is to be supposed that the capillary currents producing such deposition

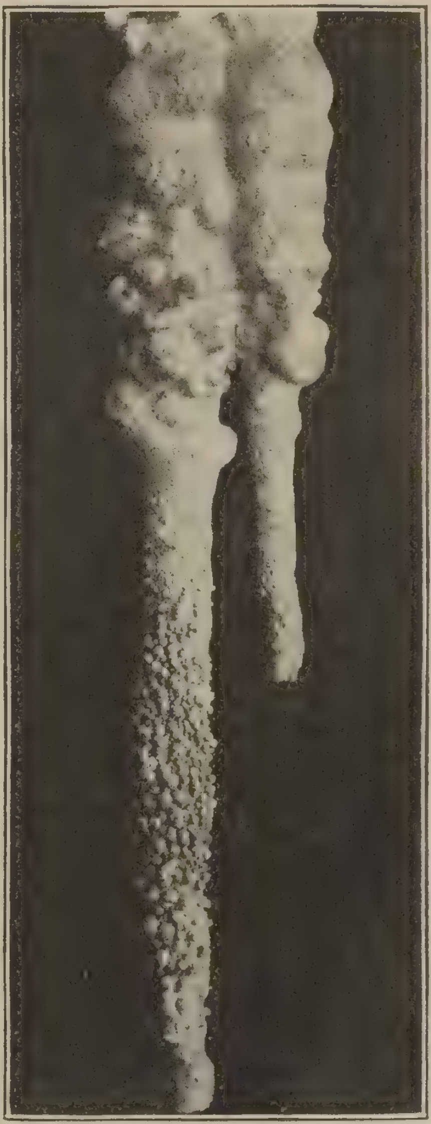


FIG. 2—Stalactite, Marengo Cave, showing form probably influenced by capillary deposit.
½ nat. size. (Mus. No. G. 963.)

---

*Abstract in Am. Jour. Sci., Vol. 160, p. 392.

would take their origin from the larger current trickling down the side of the stalactite and from the drop of water at the end. That currents rise from the drop of water at the end of a stalactite may be proved by the clumsy and not-recommended-often-to-be-tried experiment of holding a lighted candle for a moment close under the drop. The particles of soot thus left in the water will be seen to whirl about for a long time, much longer than any convection currents produced by the heat of the candle would account for. This motion continued in one stalactite which I watched for a period of five minutes, and it, may be, is still kept up. The deposit formed under the conditions of the above experiment with salt may be considered illustrative of one produced by rapid evaporation from a concentrated solution. The subject evidently admits of much further treatment experimentally by way of determining what variations, if any, would be produced in the nature and amount of the deposit by employing solutions of different strengths, by varying if possible the rate of evaporation and by the use of different salts.

THE "PILLAR OF THE CONSTITUTION."—Fig. 3. The shape and size of this huge stalagmite have often been described. It is located in the hall known as the "Senate Chamber," which is accurately

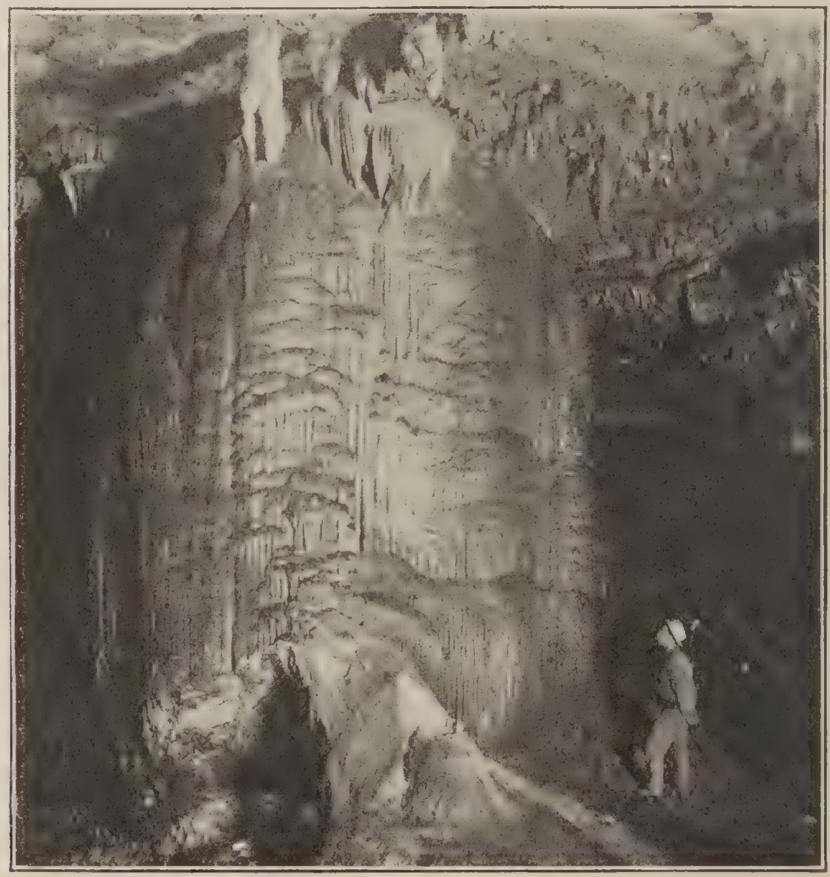


FIG 3—The "Pillar of the Constitution," Wyandotte Cave.

described by Collett* as "a vast elliptical amphitheatre * * * The sides are built up with massive ledges of limestone, thinning and converging upward into a monster dome with a flat elliptical crown 50x20 feet in diameter. The center of this vast room is piled up with a great mass of rocky debris fallen from the immense cavity above." Blatchley† gives the exact measurements of the hall, so far as its length and breadth are concerned, as 144 feet and 56 feet respectively. He gives further the following graphic description of the Pillar: "The mass of fallen rock in the center, known as 'Capitol Hill,' is about 32 feet in height, and is crowned to a depth of several feet with an immense mass of stalagmitic material. From the center of this mass rises from the top of the hill the grandest natural wonder in Wyandotte Cave—the great fluted column of satin spar or crystalline carbonate of lime known as the 'Pillar of the Constitution.' Perfectly cylindrical, 71 feet in circumference, and extending from the crest of the hill to the ceiling above, this enormous column exceeds in magnitude any similar formation in any known cave on earth." No statement of the height of the Pillar is given by this author. Collett states that the Pillar is about 35 feet high, and Mr. H. A. Rothrock, the present manager of the cave, informs me that this is undoubtedly correct, so far as the southern side of the Pillar is concerned. Owing to the fact that the stalagmite is situated a little to one side of the apex of the cone of debris, the deposit has formed about ten feet farther down on the southern side than on the northern. On the northern side, therefore, the height is about 25 feet. The mean of these, or 30 feet, may be taken as the height above the debris as a whole. The intimate structure of the mass as shown by examining fragments taken from the pit artificially excavated at its base is distinctly banded or onyx-like. The individual bands are so narrow as to be scarcely distinguishable with the naked eye, but these are grouped into series of larger bands, 0.5 mm. to 5 mm. in thickness, which differ in color or in structure so as to be plainly distinguished from one another. A secondary fibrous structure in which the fibres are at right angles to the plane of deposition has been developed through most of the bands. The latter lie for the most part nearly horizontal, but occasionally are highly contorted. The only statement I can find as to the mineralogical nature of the substance of the Pillar is that of Blatchley, who refers to it as made up of "satin spar, the purest form of carbonate of lime." Having examined somewhat carefully the substance of several hand specimens which I took from the Pillar I find them to be made up chiefly of aragonite. Not only is the specific gravity that of aragonite (2.92) as obtained by Thoulet's solution, but several cavities show the typical radiating bladed crystals of this form of carbonate of lime. The occurrence, therefore, furnishes an exception to the rule noted by Merrill* that the onyx marbles are generally calcite. Between the distinctly fibrous layers of some portions are interposed other layers microgranular and non-fibrous in structure. The substance of these I found to be of lower specific gravity than that of the fibrous layers. It is in other words, calcite. Here, then, are variations from aragonite to calcite taking place in the growth of a single mass representing corresponding variations in the circumstances of its growth. A similar occurrence is noted by Senft† in a deposit near Eisenach, Germany. It is unfortunate that our present knowledge of the conditions bringing about the formation of these two salts is so inadequate that we cannot know exactly what changes are indicated by such alternations.

---

*Indiana Geol. Survey, 1878, p. 473.

†*Op. cit.*, p. 156.

AGE OF THE PILLAR.—The immensity of this stalagmite, and the certainty that it has been formed by a fairly uniform process of deposition, lead almost irresistibly to an inquiry as to whether any satisfactory estimate of the length of time required for the formation of the mass can be made. Some attempts seem to have been made to determine the rate of deposition by measuring the thickness of the film formed upon glass vessels left in the water now dripping at the Pillar. Unfortunately these measurements are not very accurate. Collett states on one page of his report (p. 467) that water dripping "at the 'Pillar of the Constitution' has deposited a film of less than one-fiftieth of an inch during five years, or at the rate of one inch in 250 years," while on another page (p. 474) he states that "an estimate based on quasi observations places the rate of this stalagmitic growth at one inch in 100 to 150 years." Hovey, in his "Celebrated American Caverns" (p. 138), speaks of the Pillar as growing ten inches in 1,000 years, though he gives no data on which to base the statement. Mr. Rothrock, the present proprietor of the cave, has at my request had a new vessel placed in the water since my visit and it is hoped that this may furnish a means of accurate measurement in a few years. For the present, however, taking Collett's lower rate of one inch in 250 years as probably the nearest correct, it can be easily calculated that 90,000 years would have been required for the Pillar to rise to its present height had the flow of water during all this time been uniform over the constantly increasing surface. I believe it safe to regard this as a minimum age for the Pillar, though I am well aware that owing to various factors which may give rise to fluctuations of growth, geologists are accustomed to believe that no satisfactory time values can be assigned to measurements of stalagmitic deposits. See Dana's Manual of Geology, 4th edition, p. 1024. But may not these fluctuations be confined within limits as narrow as those affecting other measurements of time, such as the rate of recession of gorges or the rate of sedimentation, especially when we remember that variations in the rate of deposit almost certainly find expression in the form of the stalagmite? The stalagmite under discussion certainly has a remarkably symmetrical form. I believe, therefore, that it must have grown at a fairly uniform rate.

---

*The Onyx Marbles: their origin, composition, etc., Rep. U. S. Nat. Mus., 1893, p. 553.

†*Op. cit.*, p. 289.

Regarding the possibilities of arriving at any satisfactory value of the mean age of the Pillar, I have no very lively hope of success. It is hardly likely that the flow of calcareous waters over the entire mass of the Pillar was constant throughout the period of its growth. At the present time, growth is hardly taking place over one one-hundredth part of the surface, yet a mean value can be assigned to this factor only in a purely arbitrary way with nothing to guide the judgment that I can think of. The data for assigning an age value to the large stalagmite now in the Museum of Science and Art, Edinburgh, seem to me better founded. This stalagmite is 11 feet long and 28 inches in diameter. It was sawed from its base in a cave in Bermuda in 1819. In 1863, Sir Alexander Milne in visiting the cave measured the amount of matter formed on the base since the removal of the stalagmite and found it to be five cubic inches. At that rate it can be easily calculated that about 600,000 years were required for the formation of the stalagmite.* Numerous considerations show that it would be incorrect to apply this ratio to the formation of the 20,000,000 cubic inches of matter which make up the Pillar of the Constitution, and I introduce the illustration only to show that a much greater age should probably be assigned the Pillar than that which I have given as a minimum. In addition to the time consumed in the growth of the Pillar, a large previous period was required for the erosion of the chamber in which it stands.

---

*My data are from the Museum label. I think the facts have been published, but I cannot give the reference.

Data are meagre for estimating the length of this period. Prestwich* has estimated the rate of erosion by the Thames as one inch in 1,000 years. The chalky Cretaceous and Oölitic strata over which the Thames flows are doubtless eroded at a more rapid rate than the compact limestone in which Wyandotte cave is situated. Taking this rate, however, as a minimum, it will be found that a period of 360,000 years would be required to erode the "Senate Chamber" to the depth of the base of the stalagmite.

MARENGO CAVE.

THE CAVE FLOOR TERRACE.—The greater portion of the floor of this main cave shows a well marked terrace recording two distinct stages in the life of the stream which before its final disappearance flowed through the cave. Of these two stages the stream of the older stage had a width of from 15 to 20 feet and a current of sufficient velocity to make large ripple marks on its bed of coarse alluvium. These ripple marks are symmetrical and their long slope is plainly away from the present entrance to the cave. This, therefore, was the direction of flow of the stream. In its second stage the stream was reduced to a width of about 10 feet and its current was more sluggish. It cut a trench of the above width with nearly vertical walls to a depth of about two feet in the bed of the old stream, but did not have a current of sufficient velocity to produce ripple marks on its bed. A further greater sluggishness as compared with the first stream is indicated by the somewhat winding course which it took through the bed of the latter. The disappearance of this stream must have taken place somewhat suddenly, for there has been no trenching of its bed nor sloping of its banks such as would have occurred if the flow of water had diminished gradually. The bed, now quite dry, has a slightly concave form. A draining away of the stream by the opening of new conduits at a lower level seems the most natural explanation of its two stages and final disappearance. It is of course not impossible that these stages mark a diminution in rainfall or supply of waters from above, but there is on the whole little reason to suspect such abrupt changes in these conditions. It is not unlikely that the large spring situated a few rods west of the present entrance represents the present point of issue of the stream.

---

*Geology, vol. 1, p. 107.

STREAM DEPOSIT.—Gradual diminution in rate of flow is well shown in the deposit left by a stream tributary to the main stream to be seen at the point called the "Sand Pit" between the "Rock of Gibraltar" and "Fortress Monroe." The stream had a course nearly at right angles to that flowing through the main cave, although its course, as its channel is filled nearly to the roof, can not be followed backward except by digging. Where this tributary emptied into the main stream it formed a delta deposit about eight feet in depth. The main stream in cutting downward has cut through this delta so as to expose a complete section. The deposit is well stratified. There are slight variations in the coarseness of adjacent strata throughout the deposit, but the most striking feature is the obvious gradation from coarse pebbles at the bottom to fine alluvium at the top. The pebbles at the bottom are well rounded sandstone pebbles having about the size of English walnuts. Only a stream of considerable swiftness and volume could have transported them. From such a velocity of current the stream diminished until it bore only the finest alluvium in its latest stages. What could have led to such a diminution in its rate of flow is not apparent, but it is evident that waters flowing through limestone are liable at any time and to any extent to be drawn off in new directions by the opening of new conduits.

ABUNDANCE OF STALAGMITES.—A remarkable feature of the portions of the cave known as "Cave Hill Cemetery" and the "Prison Cell" is the relative abundance of stalagmites. Many of the stalagmites have no corresponding stalactites at all. There can be little doubt that the principles enunciated by Senft* provide adequate explanation of the origin of such results. Senft showed that when the flow of water through a crevice was too rapid, either on account of the verticality of the crevice or the abundance of the water supply, to allow of evaporation and consequent deposition sufficient to form a stalactite, a stalagmite might yet be built up because of the greater opportunity for evaporation given for water falling upon the cave floor. He supported this conclusion by calling attention to the fact that stalagmitic icicles form during the hours of the day when melting is most speedy. These suggestions seem to furnish sufficient explanation for the facts referred to.

ORIGIN OF PECULIAR FORMS OF STALAGMITES.—The form of many of the stalagmites is remarkable and, so far as I know, peculiar to this

---

Op. cit., p. 287.

cave. The form to which I refer is that of which the stalagmite known as "Washington's Monument" (Fig. 4) may serve as a type. It may be described as one which would be produced by piling a number of irregular, successively smaller, truncated, inverted cones one above the other. At first sight this structure appears very regular and suggests rhythmic variations in the supply of matter in the formation of the stalagmite. On close examination, however, it will be seen that the widenings and narrowings are not horizontal, nor do they extend uniformly around. They are rather of the nature of irregular projections and indentations. Such being the case, it seems to me that slight movements of the point of dropping of the water which formed the stalagmite would be sufficient cause for its form. Such variations in direction of growth of a stalagmite are illustrated in a section of one from Robertson's Cave, Springfield, Missouri, shown in Fig. 1, Pl. XXXII. Up to a point about one-third of the way to the top, growth was in a direction to the right. Then it turned to the left and then became more nearly vertical. Such variations might especially be expected where no stalactite existed above to maintain the point of dropping in one place, as is the case

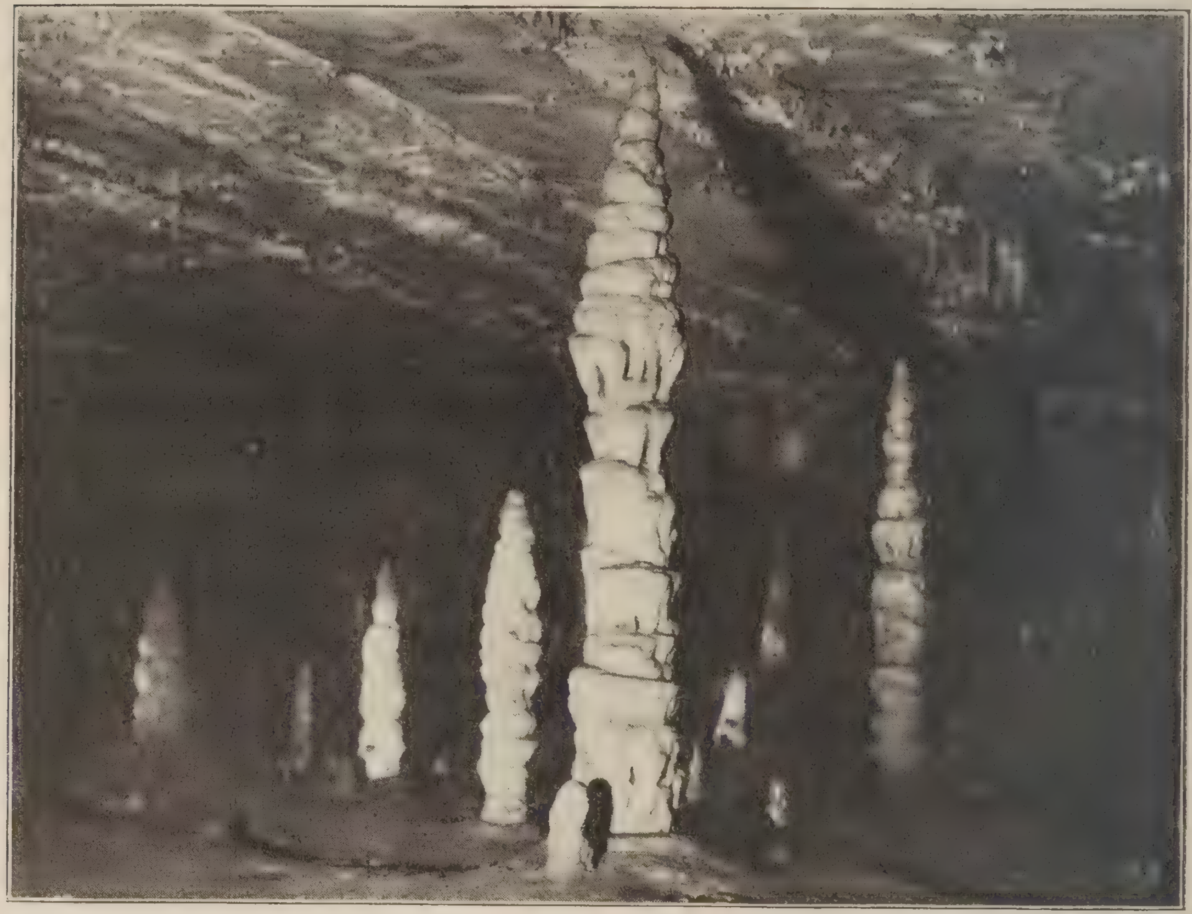
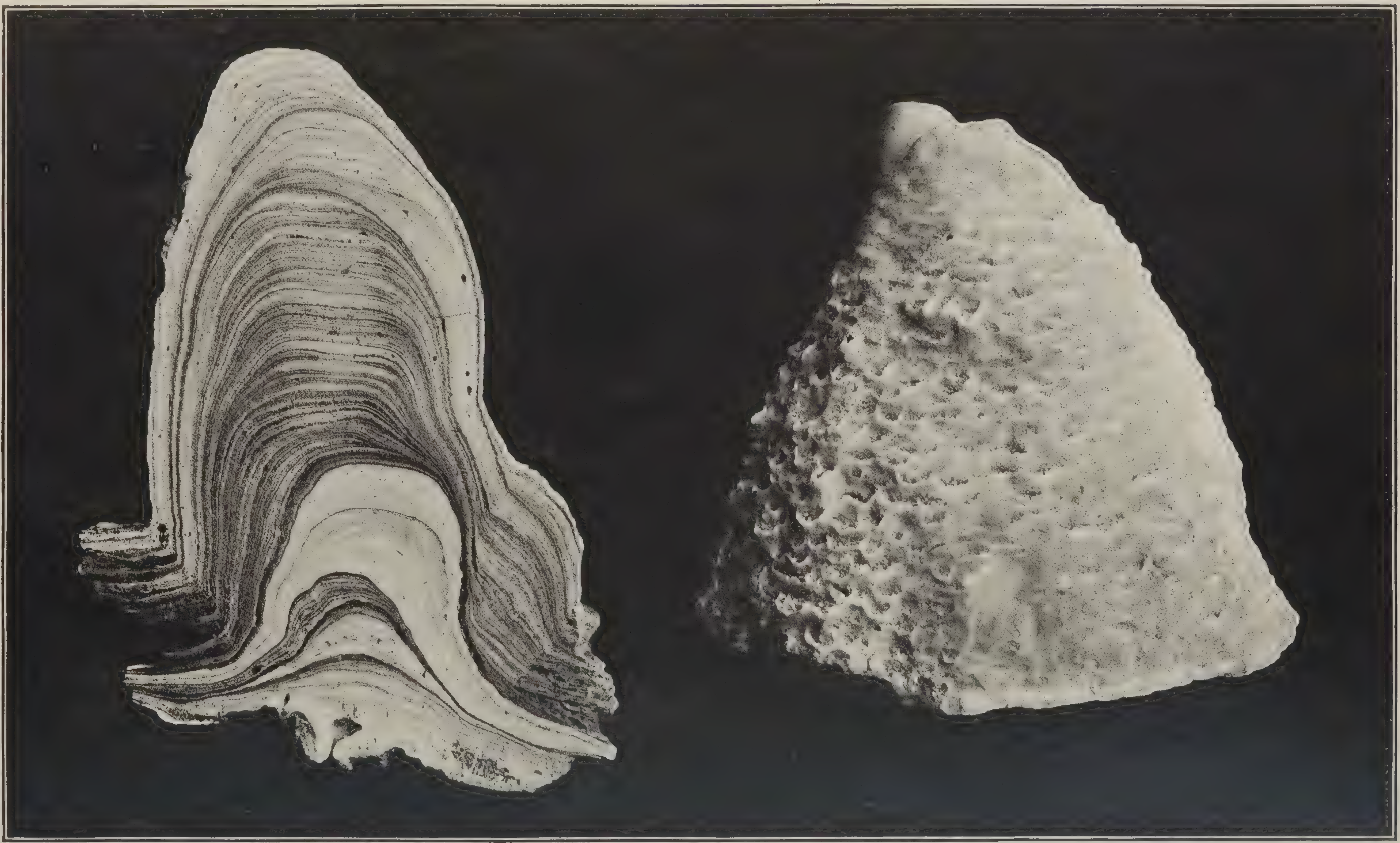


FIG. 4—"Washington's Monument," Marengo Cave.

LIBRARY
OF THE
UNIVERSITY of ILLINOIS.



EXPLANATION OF PL. XXXII.

FIG. 1. Section of stalagmite from Robertson Cave, Missouri, showing changes in direction of growth.

(Mus. No. G 604.)

FIG. 2. Cone-shaped stalagmite, Marengo Cave.

(Mus. No. G 1022.)

with those under discussion. If it be considered further that variations in the form of a stalagmite may result from variations in the rate of evaporation and content of carbonate of lime of the water which produces it, further reasons for the peculiarity of form will be added. Thus, if evaporation is rapid, or the content of carbonate of lime high, so that a large quantity of the salt contained in each drop is deposited at the top of the stalagmite and little is left to be relinquished in the subsequent course of the water down the sides, a long, slender stalagmite will be formed. If, on the other hand, evaporation is slow, or the content of carbonate of lime low, so that deposition will take place about equally during the course of the water over the stalagmite, a broadly conical stalagmite will result. It is evident that such variations occurring during the growth of any single stalagmite would find expression in corresponding forms in different parts of the stalagmite.

Another form of stalagmite so far as I know peculiar to this cave is that of a flattened cone. Such are the stalagmites known as "Mt. Vesuvius" and the "Diamond Dome." The form is illustrated by Fig. 2, Pl. XXXII, showing a stalagmite collected by the writer at the cave. I have indicated above in what manner slight evaporation as compared with the rate of flow of water or a relatively low content of carbonate of lime might be expected to produce such a form. It may be further noted that the lateral surface of these stalagmites, instead of being smooth like that of the ordinary stalagmite, is built out in a series of sinuous walls running more or less horizontally around the cone. These walls form numbers of little pools usually filled with water and containing delicate crystalline aggregations of carbonate of lime. The low slope of the surface allowing slow movement of the water over it is doubtless responsible for the construction of these walls.

STALAGMO-STALACTITES.—Usually in the growth of cave formations, a stalactite forms above its counter stalagmite. An odd reversal of this condition of things so that the stalagmite forms above the stalactite is to be seen in several instances in this cave, the formation known as the "Mermaid" being perhaps the best example. Such stalagmo-stalactites are formed by a drip taking place on the edge of a limestone shelf so that the water which builds up the stalagmite, in pursuing its further downward course forms a stalactite as well. Of the general appearance of such formations Fig. 5, showing a specimen collected in Shiloh Cave, will give a sufficient idea.

MOLECULAR ARRANGEMENT OF STALACTITES AND STALAGMITES.—The substance composing the stalactites and stalagmites of this cave is generally made up structurally of fibres radiating outward from the center. The fibres pass uninterruptedly through the concentric rings of growth and the structure is doubtless, therefore, as pointed out by Merrill,* of secondary origin. The fibrous substance is not, however, aragonite, but calcite. In contrast to the forms possessing this structure are many whose substance has a wholly coarsely-crystalline structure exhibiting an all-pervading rhombohedral cleavage. Intermediate stages between these two extremes can be seen in many cases. Of especial interest are stalagmites exhibiting a structure like that shown in Fig. 6. This figure shows a cross section of a stalagmite, the peripheral portions of which are fibrous in structure while the central are rhombohedral. I am of the opinion, though I know of no way either of proving or disproving it, that such a structure is evidence of a progressive change in the molecular arrangement of the substance toward a more stable condition. It is certain that it is in the older portion of the stalagmite that the molecules are arranged along the rhombohedral planes, and I have never found the positions reversed. That the rhombohedral condition is more stable than the fibrous seems to be indicated by the fact that the former is characteristic of the oldest and most metamorphosed calcite-bearing rocks. Prof. D. G. Elliot has suggested to me that pressure on the internal substance of the stalagmite may also be largely instrumental in bringing about the change to a rhombohedral condition. This is not unlikely. But whatever the determining causes, the case seems to furnish an instructive illustration of

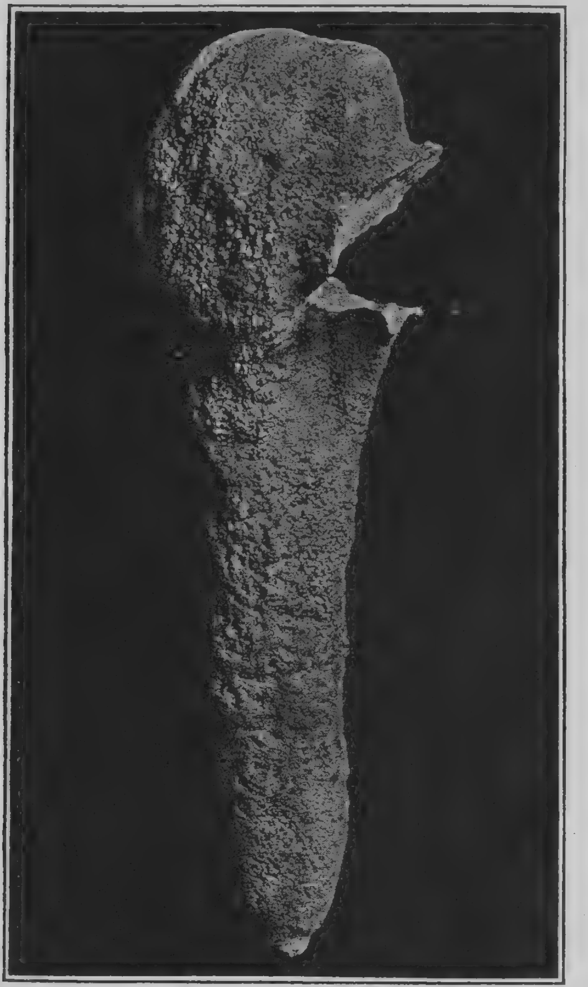


FIG. 5—Stalagmo-Stalactite, Shiloh Cave.
(Mus. No. G. 884.)

---

*Op. cit., p. 78.

progressive molecular arrangement. The carbonate of lime was deposited first in narrow, concentric bands. The substance then rearranged itself in the form of more or less continuous fibres arranged at right angles to the planes of deposition. Then with the lapse of time and pressure a second rearrangement was made by which the attractive forces brought the molecules together grouped along rhombohedral planes.

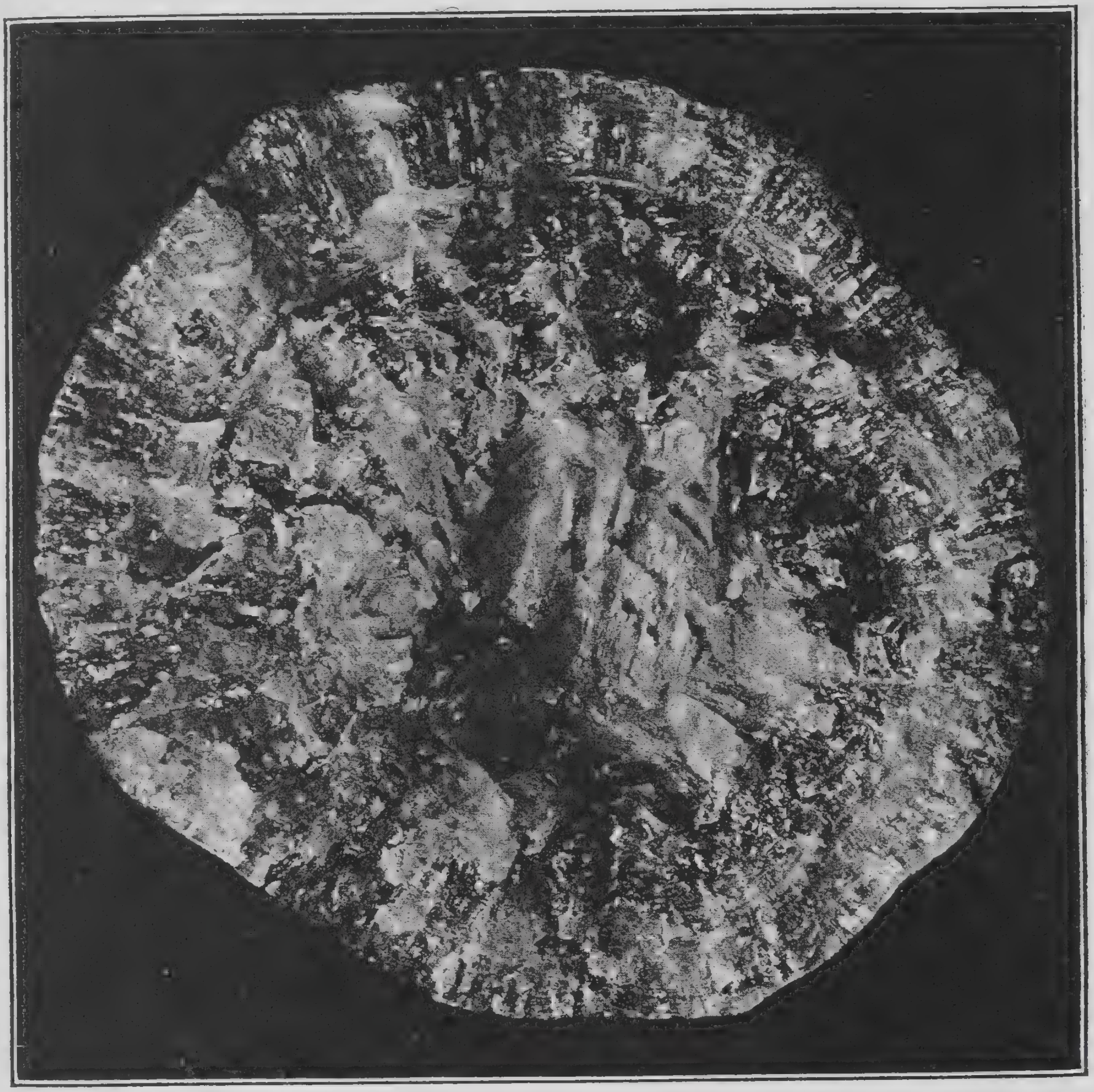


FIG. 6—Broken end of stalagmite, showing change from fibrous to rhombohedral structure.

RATE OF GROWTH OF STAGMALITES.—I propose this word, compounded from στάγμα (drop) and λίϑος (stone), as a general name for formations produced by dropping water.

Under the present usage the expression stalactites and stalagmites, each term of which has a limited meaning, is the only one available. So many stagmalites in this cave are in process of formation that it seems a favorable place for a study of their rate of growth and of the variations which occur in this rate. In the hope of obtaining, in the lapse of years, some data on this point Mr. S. M. Stewart, manager of the cave, kindly allowed, at my request, several stalactites and one stalagmite to be marked by Mr. Claude Stroud, who lives near the cave, and who, by keeping watch of their growth, can note any variations which they undergo. It will be understood, however, that the rate of growth is so slow that it is not likely that before the end of ten years at least any appreciable change will have taken place. The record of the stalactites marked is as follows:

No. 1 Near "Tower of Babel," Drops at intervals of 3½ minutes.
No. 2 In "Queen's Palace," " " " " 45 seconds.
No. 3 " " " " 216 times per minute.

These are simple stalactite tubes.

The stalagmite marked is in "Crystal Palace Gallery," and receives eighteen drops a minute.

SHILOH CAVE.

ERODED STALACTITES.—The stalactite shown in Fig. 7, occurring near the southern end of the cave, furnishes an interesting illustration of the fact that cave waters may vary in their action from formative to erosive, according to the quantity of carbonate of lime they contain. Thus, in the case of the stalactite here represented, the waters flowing over the limestone shelf to which it is attached had at one time built it up to the general form shown. Later, however, the character of the waters changed and they began to erode, as shown by the pits on the surface, the very mass they had previously built up. These processes of deposition and erosion are, of course, going on side by side in nearly all limestone caves, but it is not often that erosion follows so rapidly after deposition. Many smaller stalactites in other parts of the cave show similar erosion.

LEAF STALACTITES.—Many of the stalactites of this cave are leaf-like in their form so far as this may describe a broad, thin and pointed shape. Often the appearance is that of a series of ovate leaves folded along their midribs and hanging down from a projecting ledge. The "leaves" of one such projecting mass are nearly six feet in length, and the weight of the mass must be several thousand pounds. It is remarkable that such a weight can be sustained

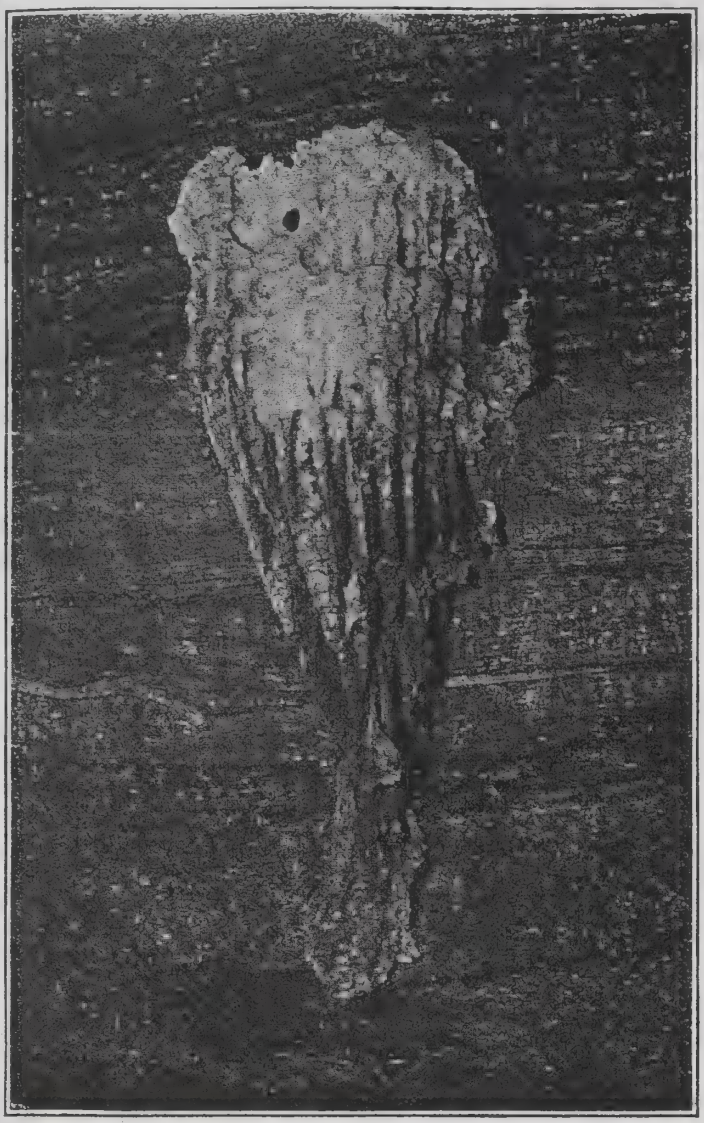
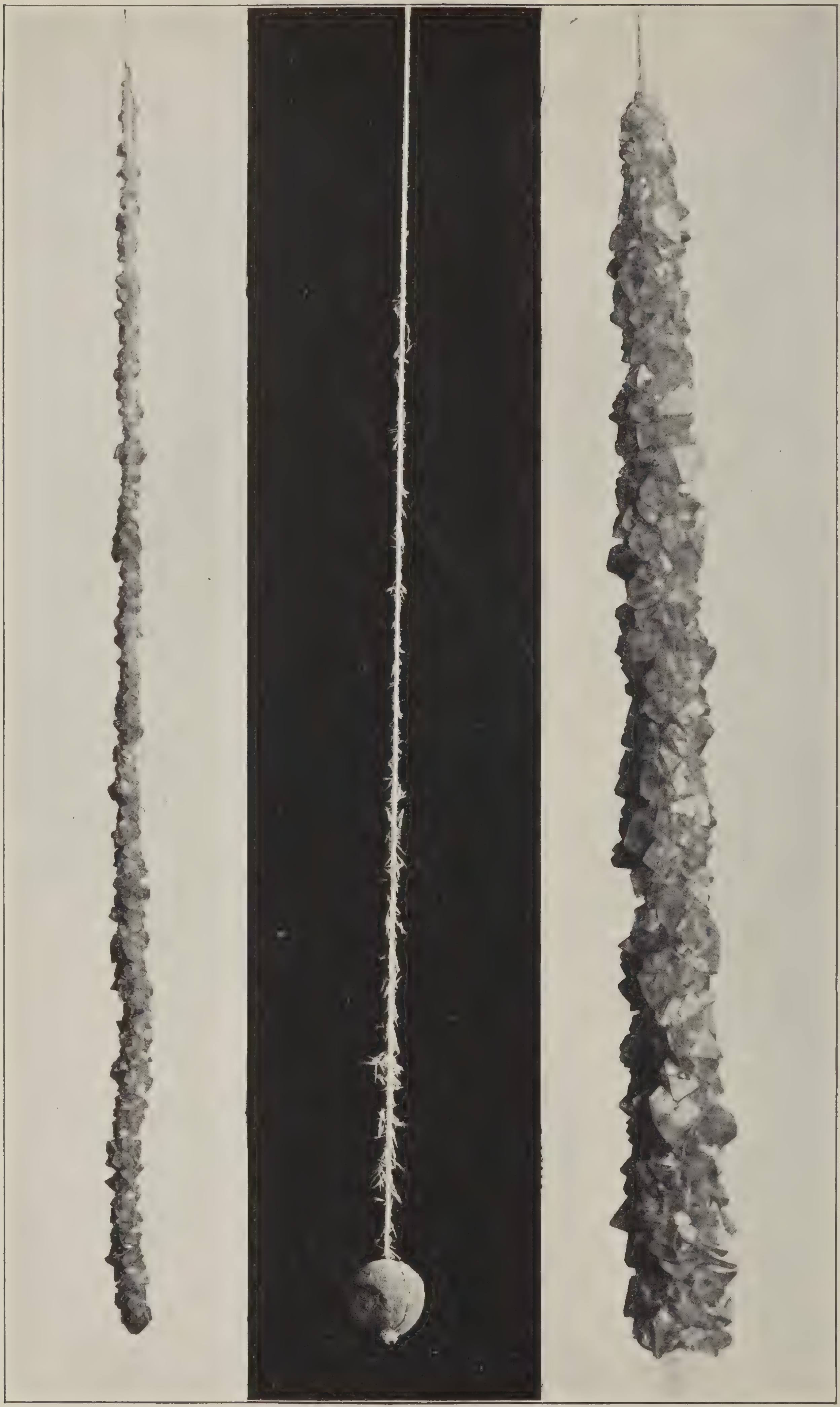


FIG. 7 —Eroded Stalactite, Shiloh Cave. (Mus. No. G. 881).

as it is at right angles to the wall. Observation of the broken end of any of the "leaves" of such a group of stalactites will show the manner of growth. (See Fig. 8.) Such growths are not formed by water trickling down a crevice, but from currents debouching over a limestone shelf. The shelf must project slightly and the current of water must be relatively large. There are first formed stalactites of the ordinary conical type. Then deposition is confined only to one side of the stalactite, the side, namely, over which the descending water flows. Growth takes place then almost wholly in this direction and in the direction of length. A deposit is, however, also built up from the surface of the shelf by the water flowing over it. So the mass grows upward in a thin layer, downward at the stalactite points and outward in thin sheets at right angles to the cave wall. There is also a slight lateral growth of the stalactites which causes them in time to join one another, and the group thus acquires the appearance of a continuous sheet thrown into folds. The original stalactite points usually continue to be the points of greatest growth in length, but the stalactite may be longest some distance away from these. Corrugations of the surface showing retardations of the flowing waters, and similar to those so common on icicles, are nearly always present. If the current is comparatively narrow and maintains its position for a long period of time the stalactitic mass will take a semi-circular form owing to the fact that the portions in the center of the current receive more material than

LIBRARY
OF THE
UNIVERSITY of ILLINOIS.



EXPLANATION OF PL. XXXIII.

Strings of crystals obtained from solutions of copper sulphate, lead chloride and nickel-alum, showing increase in size of crystals and amount of deposit toward the bottom of the solutions. A shot used to weight the string appears in the central figure.

The most unique feature of this cave is the pool at its end, excellently described by Blatchley.*

The calcite crystals which line the walls of the pool are made up of the unit rhombohedron r $(10\bar{1}1)$ and the unit prism of the first order m $(10\bar{1}0)$. (Fig. 9.) The crystals have all grown in a direction at right angles to the plane of their attachment. The prism is quite short, and no crystals are doubly terminated. The crystals vary in size from quite minute to those the size of an ordinary acorn. It is noticeable that they increase in size toward the bottom of the pool. In order to determine whether it was commonly true that crystals increased in size toward the bottom of a solution, with the assistance of Mr. H. W. Nichols, I prepared solutions of a number of salts, placed them in long slender jars and then immersing strings vertically, noted the quantity and size of crystals deposited. In nearly every case the deposit took a marked conical form. The base of the cone and therefore the greatest amount of deposit was at the lowest point in the solution. It was also generally true that the size of the crystals increased toward the bottom. The accompanying plate (Pl. XXXIII), showing strings of crystals obtained from solutions of copper sulphate, lead chloride and nickel-alum, illustrates this. Such results point to a greater concentration of solutions at the bottom, a principle already established with regard to solutions in general by Ludwig and Soret.† It may be worth while, however, to call attention to this illustration of the principle, and to the fact that the size of crystals depends on the degree of concentration of the solution no less than on the time given for their formation.

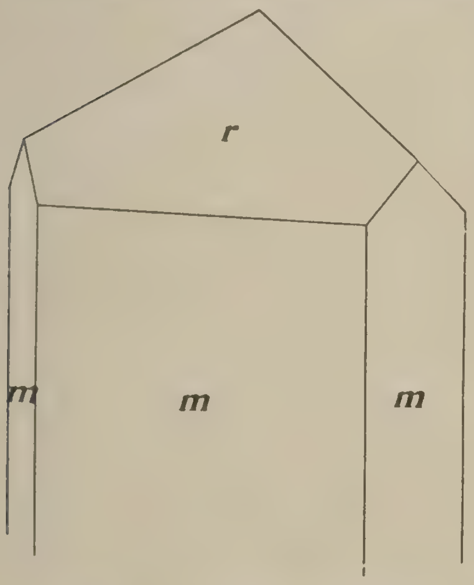


FIG. 9—Calcite, Coan's Cave.

In this part of the cave stalactites and stalagmites of the ordinary type appear in close association with the crystal deposits just described. The formations have a similar origin in that they are both deposits of carbonate of lime from solution in water. They differ only in the condition that in the making of stalactites and stalagmites the water was moving, while in the making of crystals it was still. If I am correct in this conclusion the converse of the principle affords a rule perhaps of some value as a guide to the conditions under which banded formations have taken place as compared with those which exhibit distinct crystals. Substances deposited from solution in water which exhibit a banded or layered structure have, according to this rule, been formed by moving waters, while those in the form of distinct crystals have been deposited from waters at rest. Hence, the banded structure so characteristic of mineral veins may be considered proof that the deposit was formed from moving waters while the occasional cavities lined with crystals show points at which the solutions were at rest. Similar conclusions may be drawn regarding the same structures as seen in agates and geodes. It is evident, further, that the conditions in the two cases also differ in the quantity of liquid present and in the rate of deposition. The layered structure is the result of *trickling* waters from which deposition is necessarily rapid, while the distinct crystals were formed from a solution which was present in quantity, and from which deposition was comparatively slow. The applications of these principles to conclusions regarding the origin of veins are obvious. The terms motion and rest are, of course, here to be understood in a purely relative sense, as no body of liquid would be entirely free from internal currents. Further, it is to be granted that all gradations may be traced between a banded structure and distinct crystals. In a broad sense, however, the rule stated in these terms may be of some value.

**Op. cit.*, p. 132.

†Becker, Am. Jour. Sci., Vol. 153, pp. 21-40.

FIELD COLUMBIAN MUSEUM

PUBLICATION 60.

GEOLOGICAL SERIES. VOL. I, NO. 9.

THE DINOSAUR BEDS OF THE GRAND RIVER VALLEY OF COLORADO.

BY

ELMER S. RIGGS,
Assistant Curator, Department of Geology.

OLIVER CUMMINGS FARRINGTON, PH.D.,
Curator, Department of Geology.

CHICAGO, U. S. A.
September, 1901.

THE DINOSAUR BEDS OF THE GRAND RIVER VALLEY OF COLORADO.

During the spring of 1899, while in correspondence with Dr. S. M. Bradbury, President of the Western Colorado Academy of Science, the writer's attention was called to the occurrence of vertebrate fossils in the Valley of the Grand River. The presence of these fossils had been locally known for fifteen years and they had been more or less collected as curios, but no paleontologist had investigated the matter and no report of their presence had been given to the scientific world. Knowing that the older collecting grounds for Dinosaur fossils were rapidly being culled, and aware of the possible importance of discovering a new field, plans were at once made looking toward the investigation of this locality. However, it was not until the following spring that a Museum expedition could be organized and sent into this region for the purpose of collecting fossils. The three months so employed yielded such important returns that early in the past year the work was resumed with equally gratifying results.

The Jurassic* formations of the Grand River Valley were originally described by †Peale in the Survey of Colorado, but some further description, based upon observations made during the two summers spent there, and illustrated with photographs by Mr. H. W. Menke of the Museum, may be of interest.

On the southern bank of the Grand River the Uncompahgre Plateau breaks away in a series of benches and folds to the level of the valley below. The western half of this plateau is made up chiefly of the Jurassic and Triassic formations, although retaining in many places a capping of lower Cretaceous. Farther west the Valley of the Dolores has cut through these formations into the underlying Carboniferous. In the cañons formed by its tributaries, as well as those of the Grand River, the whole depth of the Jura-Trias is exposed.

---

*These beds have been variously designated as: "Lower Dakota Group" (Peale, U. S. Geological and Geographical Survey of Colorado and Adjacent Territory, p. 179); "Atlantosaurus Beds" (Marsh, Amer. Jour. Sc., third series, Vol. XXI., p. 411), and "Como Beds" (Scott, An Introduction to Geology, p. 477; Williston Amer. Jour. Sc., fourth series, Vol. XI., p. 114). While the consensus of opinion among later writers would place the fresh-water deposits in the lowermost Cretaceous, contemporary with the English Wealden, for reasons which will later appear they will be referred to in this article as Jurassic.

†Peale, op. cit., p. 170–180.

Approached from the Grand River Valley, the most conspicuous landmark is the high and abrupt Triassic bluff which forms the valley's southern confine (Plate XXXIV). For several miles to the southward the massive red sandstone has been denuded of its Jurassic covering and so has received the name of Red Mesa (Plate XXXV). Some distance from the face of this bluff isolated buttes and ridges of Jurassic clays appear, and farther still to the southward the whole thickness of this formation is exposed in the fantastically weathered shapes of typical bad lands. The top of the Jurassic strata is covered with a heavy growth of pines and hence is geographically known as Piñon Mesa. All of these strata dip in a general way to the northeast and with the Book Cliffs, which bound the valley on the north, form a great monocline (Plate XXXIX). This is, however, varied by many local complications.

Along the lower course of the Gunnison River, the strata forming the crest of the Piñon Mesa sweep down to the valley level in a great undulating fold. In this the Jura-Trias has been but little broken or crumpled, although it is now deeply furrowed by later cañons of erosion. Here the Jurassic clays, protected by a heavy capping of Dakota sandstone, extend quite to the river bank. A few miles west of Grand Junction however, this fold gives place to a fault of more than one thousand feet. Farther along the line of bluffs to the northwestward the strata are again continuous in a more or less interrupted fold (Plate XXXVI) until at a point sixteen miles west of the mouth of the Gunnison the crest of this fold is broken by a fissure through which the Grand River has cut its cañon.

Along the line of this fault the Triassic sandstone is exposed in an almost perpendicular bluff standing high upon a bench of igneous rocks consisting chiefly of a coarse-grained granite (Plate XXXIV). Against this igneous bench occasional masses of Triassic sandstone lie tilted at high angles. A short distance toward the river the Trias resumes its almost horizontal position and still nearer the river appears a series of Jurassic bluffs facing the line of fault and dipping in the general direction of the monocline. (Plate XXXVIII.)

STRATIGRAPHY.

In this region the Trias is represented by a massive ledge of reddish sandstone, slightly cross-bedded, and weathering in peculiar pinnacle and dome-like shapes (Plate XXXVII). Below this is a softer stratum of vermilion-colored sandy shale resting directly upon the igneous rock. The whole thickness of these ledges is about 400 feet.

The Jurassic strata range from 600 to 700 feet in thickness and may admit of four sub-divisions (Plate XXXIX). The lower or marine Jura is from 100 to 120 feet in thickness and consists of bluish and grayish gypsum-bearing clays in which thin layers of fine-grained sandstone and nodular ledges of limestone are interspersed. The latter are never more than six or eight inches in thickness and are usually from three to five in number. In no instance were fossils found in these measures. The change from marine to fresh-water Jura is scarcely noticeable and can be traced only by the absence of limestone and the more homogeneous and massive nature of the clays. There is, however, near the base of the fresh-water formation a ledge of fine-grained brown sandstone which is noticeable from its peculiar honeycomb weathering.

Above the marine Jura lies a stratum of greenish clay shale about 100 feet in thickness. It contains occasional ledges of homogeneous green sandstone and a few layers of clay nodules, but nowhere is there a marked color-banding. Above the green shale, which may be spoken of as the lower beds, comes a darker zone of 40 or 50 feet containing frequent ledges of cross-bedded sandstone. These vary from a fine-grained sand occurring in thin layers to a massive coarse-grained sandstone, rich in iron and weathering to a brownish red color. The latter sometimes reaches a thickness of 20 feet toward the western end of the exposures described. Throughout the series there is a noticeable tendency toward thinning out and being replaced at slightly different levels. In places the sandstone disappears entirely and the green shales below grade into the banded clays above.

The variegated clays reach a thickness of 300 or more feet and are conspicuous on account of their brilliant horizontal banding as well as the typical bad-land shapes into which they weather (Plate XXXVIII). The alternation between green and purplish bands does not mark any variation in the nature of hardness of these massive joint clays. There are frequent layers of clay nodules, sometimes calcareous, and a few ledges of nodular gray sandstone which are confined to limited areas. Occasional thick ledges of cross-bedded sandstone and lenticular masses of greenish sand occur at almost all levels, but these are likewise of limited extent. Throughout the lower measures of this horizon are abundant nodules of secondary formation, sometimes occurring in irregular strata, but often scattered promiscuously through the clays. Near the top the banding is least pronounced, and the clays take on a more sandy nature. Just below the capping ledge of sandstone there is often a thin stratum of darker shale which bears traces of carbonaceous matter; at other places it takes on a mottled color and a pebbly texture.

The Jurassic clays are capped by a massive ledge of sandstone varying in this locality from ten to twenty feet in thickness, It is coarse-grained in texture and abounds in quartzitic nodules often so massive as to occupy the greater part of the ledge. When freshly broken it has a decided yellowish color, but after weathering it changes to a dark brown. At the base there is often a stratum of fine-grained and more homogeneous sandstone. In certain localities this ledge contains the wealth of fossil leaves which everywhere distinguishes the Dakota sandstone.

With regard to the line of demarkation between the Jurassic and Cretaceous, the writer cannot agree with the determination of the Hayden Survey in this locality. Writing of the Jurassic in the upper valley of the Gunnison, Peale says:[*] "The massive yellow silicious sandstone, in some places quartzitic, at the base of the Cretaceous, is so well defined lithologically that there has never been any difficulty in separating it from the overlying shales. Along the edge of the plains in Colorado it is underlaid by greenish, shaly beds, sometimes lignitic toward the top, generally in part or wholly covered, which have always been referred to the upper part of the Jurassic." This description will apply to the same formation in the Grand River Valley, but writing of the Grand River Valley a year later the same writer says: "The line separating the Jurassic from the overlying Dakota is indefinite."[†] The following section referred to the Cretaceous shows how far he has digressed from the conclusions of the previous year:—

"The following is the average of the Dakota group in the hog-backs of the Grand River:

1. Massive yellow silicious sandstone with faint impressions of dicotyledonous stems at some localities - - - -	90–200
2. Variegated marls with bands of reddish sandstone. These beds have the characteristic weathering of bad lands -	
3. Dark colored sandstones with bands of marls and shales. Near the base a layer containing nodules in which there are jaspers - - - - - - - - - -	50–100
Total thickness - - - - - - -	140–300"

---

[*] U. S. Geological and Geographical Survey of Colorado and the Adjacent Territory, 1875, p. 88.

[†] U. S. Geological and Geographical Survey, 1876, p. 180.

In this section the massive sandstone ledge is the characteristic Dakota sandstone referred to in the eastern Gunnison region as marking the base of the Cretaceous. From its well-known lithological character, as well as the abundance of dicotyledonous leaves found in it, there can be no doubt that it is the same which caps the Como Beds* at Cañon City and Trinidad, Colorado, and at Como Bluff and in the Freezeout Hills of Wyoming. In fact so persistent is this ledge and so marked is its effect upon the land sculpture, owing to its resistance to erosion, that it has come to be expected as a capping ledge wherever the beds occur. The variegated marls have the same lithological characters as the upper measures of Como Bluff and have been lately reported† from Trinidad, Colorado.

The dark colored sandstones described under 3, though persistent at approximately the same level are by no means continuous. The writer has traced this level from the valley of the Gunnison to the point where Grand River enters the cañon and in a distance of twelve miles these ledges thin out and re-appear no less than five times. At the mouth of the No-thoroughfare Cañon, the sandstone strata are wanting entirely and the clays show not only a continuous deposition from the marine Jura to the base of the Dakota sandstone, but the color-banding grades evenly from the green shale below to the banded clays above. The same is quite as true at other points where the sandstone ledges thin out.

Moreover, the characteristic fossils of the Como Beds occur more abundantly in the variegated clays than in the green shales below. Nowhere are they so abundant as in the cross-bedded sandstone ledges. Representatives of a single genus (*Morosaurus*) have been observed to range through the entire series. It is therefore evident that no important sub-division can be made of these beds. Whether Jurassic, as they have been usually considered, or lowermost Cretaceous and contemporary with the Wealden, as held by some, these measures should be regarded as identical with the Como Beds and treated as a close series having only such sub-divisions as are suggested on page 269. And if stratigraphy is of any value in determining the relationships of formations, the closely connected series of sediments extending from the base of the marine Jura to the base of the Dakota sandstone certainly has a story to tell. Here, as in many localities observed throughout the states of Colorado and Wyoming, the marine Jura and the fresh-water beds are so intimately related as to admit of no hiatus. If it then be proved that the relations of the fresh-water fauna to that of the Wealden indicate contemporaneity rather than an accelerated development of reptilian life in America, as might well be the case, we must conclude that the barren zone of green clays lying between the marine Jura and the fossil-bearing horizon has bridged the gap between Jurassic and Cretaceous.

---

*Scott, An introduction to Geology, p. 477, Williston Amer. Jour. Science, Vol. XI., p. 114.

†Lee, Journal of Geology No. 4, 1901.

From their lithological characteristics, as well as the nature of their weathering, the variegated clays might well be mistaken for Eocene bad lands. They are made up of the same sort of indurated clays, firm as sandstone under the pick, but readily dissolved and yielding rapidly to erosive agencies. There is also the same brilliant horizontal banding, the same nodular layers, the same cross-bedded and interrupted ledges of sandstone, and the same variation of hard and soft strata which gives the characteristic bench-like profile common to these formations. In short, so close is the resemblance to the Wind River Eocene of central Wyoming that were it not for the fossils one might be justified in regarding the two as identical.

OCCURRENCE OF FOSSILS.

The fossils found in this region are, with few exceptions, vertebrate. One invertebrate fossil (*Viviparus*) is found abundantly in one or two localities and is of interest in being chalcedony-filled. The vertebrates so far as observed, are confined to the order Dinosauria, but are quite abundant. The forms are the common types of the Como Beds as found in eastern Colorado and in the well-known localities of central and southern Wyoming.

As before stated, the marine beds have so far produced no fossils, and the greater part of the green shale of the lower fresh-water beds seems to be barren. The lowest point at which fossils have been found is twenty feet below the top of these beds. From this point upward they rapidly increase in abundance. In fact the thin stratum of dark shale, lying just below the cross-bedded sandstone, and the lower ledges of this sandstone are the richest in fossils of all these deposits. In certain localities however, the whole series of sandstone abounds in fossils. In the variegated clays, Dinosaurs have been found at all levels from the base to within a few feet of the capping Dakota sandstone, but are usually confined to the lower 150 feet.

No general deposits of fossils such as are found in eastern Colorado and southern Wyoming have been discovered in this locality. In the clays seldom more than one individual is found in a place and these have the bones but little displaced from their relative positions.

This fact, as well as the homogeneous nature of the clays, suggests that their deposition took place in comparatively still, if not deep water. In the sandstone ledges, however, the positions of the bones show that they have been carried about. Rarely more than the parts of a leg or a short series of vertebræ have been found connected, and more often isolated bones are found. This, taken in connection with the varying coarse and fine-grained sands and the persistent cross-bedding, is conclusive evidence of deposition by water currents. In fact the abundance of fossils in certain pockets of this sandstone and the manner of their occurrence are very similar to those of the Metamynodon Beds of the White River Oligocene in South Dakota. The sandstone ledges are of course more massive, but in their relation to the clays above and below there is evidence of a similar set of conditions. The varying clays with the horizontal banding and frequent nodular ledges also correspond closely to the clays comprising the Oreodon Beds of the White River.

Let us attempt to trace the history of the Jurassic formation as evidenced by the nature of the rocks, the stratigraphy and the occurrence of fossils: Given an arm of the Jurassic sea, fed by rivers and open to the ebb and flow of tide waters. Under these conditions the sediments washed down by the river everywhere accumulated slowly, and alternating with them thin ledges of limestone and gypsum were laid down. Occasional strata of sand accumulated by the action of retarded currents about the estuaries of streams. Later, by some change in levels, the ingress of sea water was cut off, but the outlet still remained and so ensued the gradual change from salt to fresh water. Then followed a period of comparatively uninterrupted deposition in which the green shale was laid down under still water. Along with it were deposited near the mouths of streams the occasional homogeneous beds of green sand. As the basin filled up and its outlet deepened, the lake became shallower until its bed was invaded by the shifting channels of broad and shallow streams. Its sand-bars have formed the cross-bedded sandstone ledges which mark the transition from the lower to the upper clays. With the shallower waters came the great land and shore reptiles and about the estuaries of streams their remains were deposited abundantly.

Again the lake waters invaded the region and the deposition of sand in this locality was cut off. The period following was one of greater changes and probably of slower deposition than that preceding the river period. The presence of fine reeds or sedges shows that the water was shallow, at least in places, and parts of skeletons found on irregular surfaces imbedded in these reedy clays, suggest mud-bars or islands on which they have stranded. In one instance part of a skeleton found imbedded in a stratum of blue clay which thinned out and was replaced by sandstone with pebbles at the base, indicates that the carcass was buried in a mud-bank bordering a stream or water-current. The interruption of the vertebral column and the displacement of the ribs in one direction show that the stream was sufficient to carry away the missing part of the skeleton.

The tendency toward a more shaly nature and the presence of carbonaceous matter in the upper measures indicate the return of shallows and the greater abundance of vegetable matter. This condition evidently culminated in the great influx of sand laden with deciduous leaves which marks the period represented by the Dakota sandstone.

EXPLANATION OF PLATE XXXIV.

Fault in Triassic sandstone produced by up-thrust of granite. Exposure of granite is seen in the middle ground at the right. On the left the Triassic strata are seen highly tilted and resting upon the granite. In the foreground and at the crest of the bluff these strata show only a slight dip in the direction of the monocline.

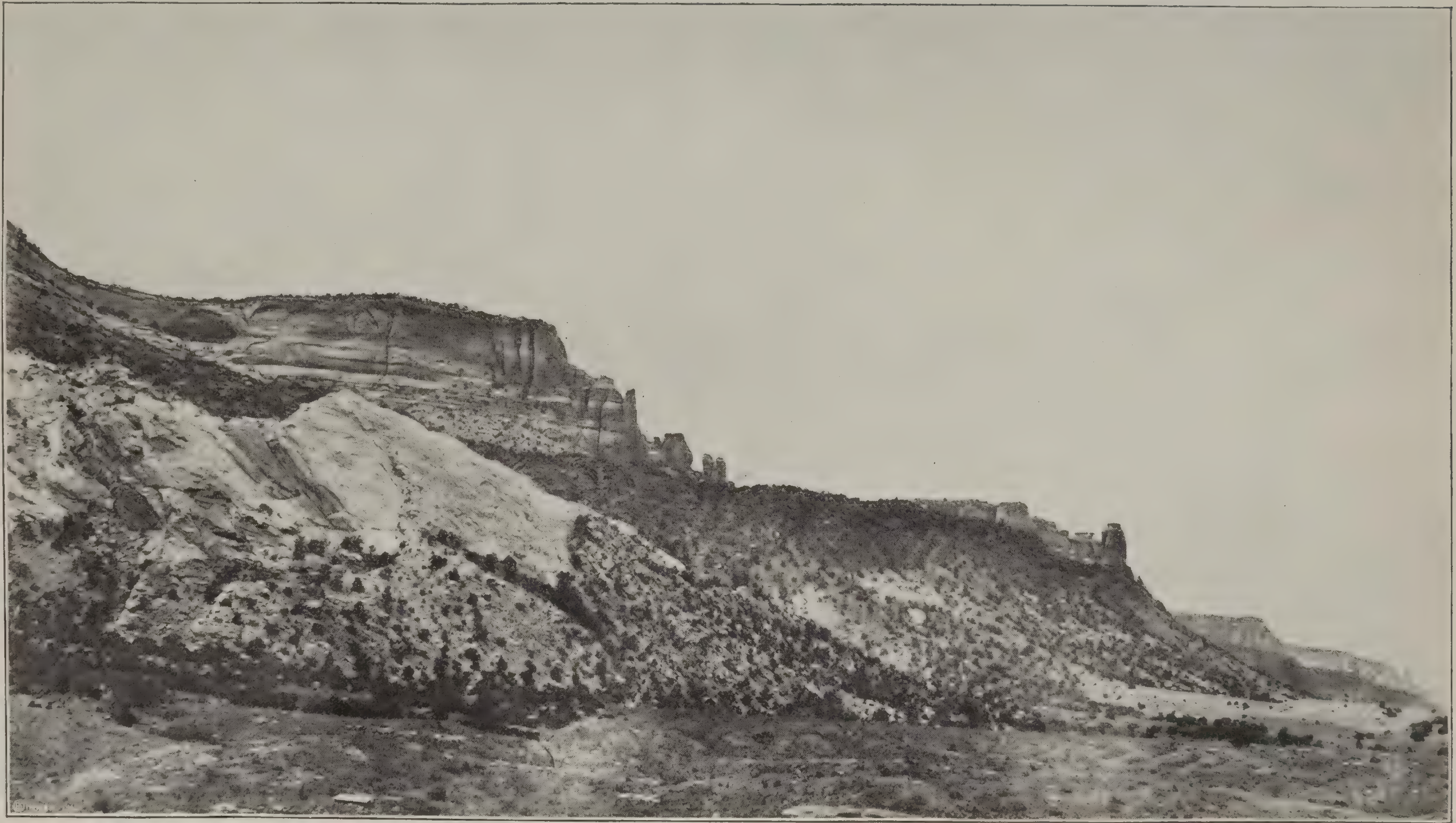
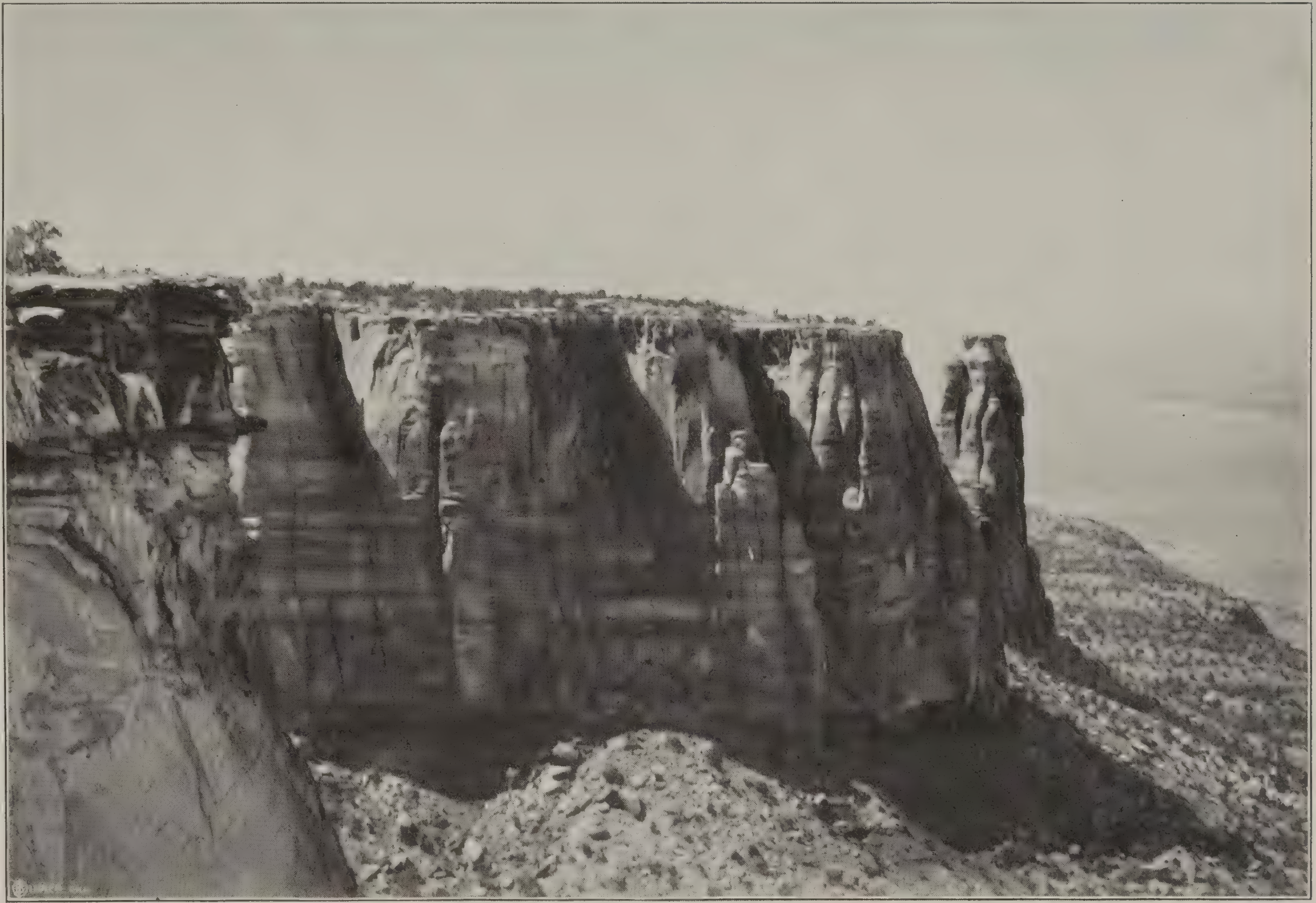


Photo. by S. M. Bradbury.

LIBRARY
OF THE
UNIVERSITY OF ILLINOIS

EXPLANATION OF PLATE XXXV.

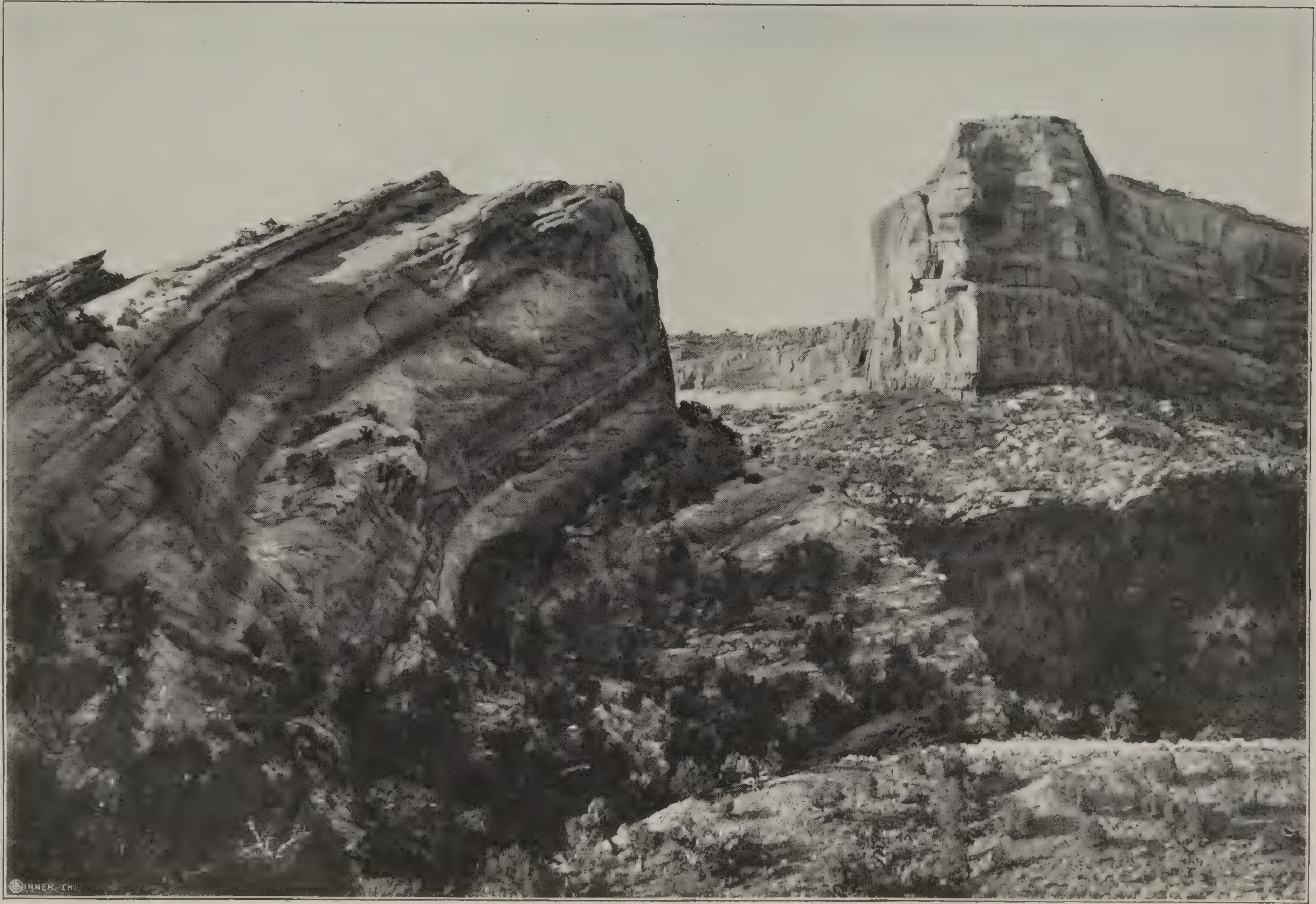
Triassic sandstone as exposed at the brow of Red Mesa.



LIBRARY
OF THE
UNIVERSITY OF ILLINOIS

EXPLANATION OF PLATE XXXVI.

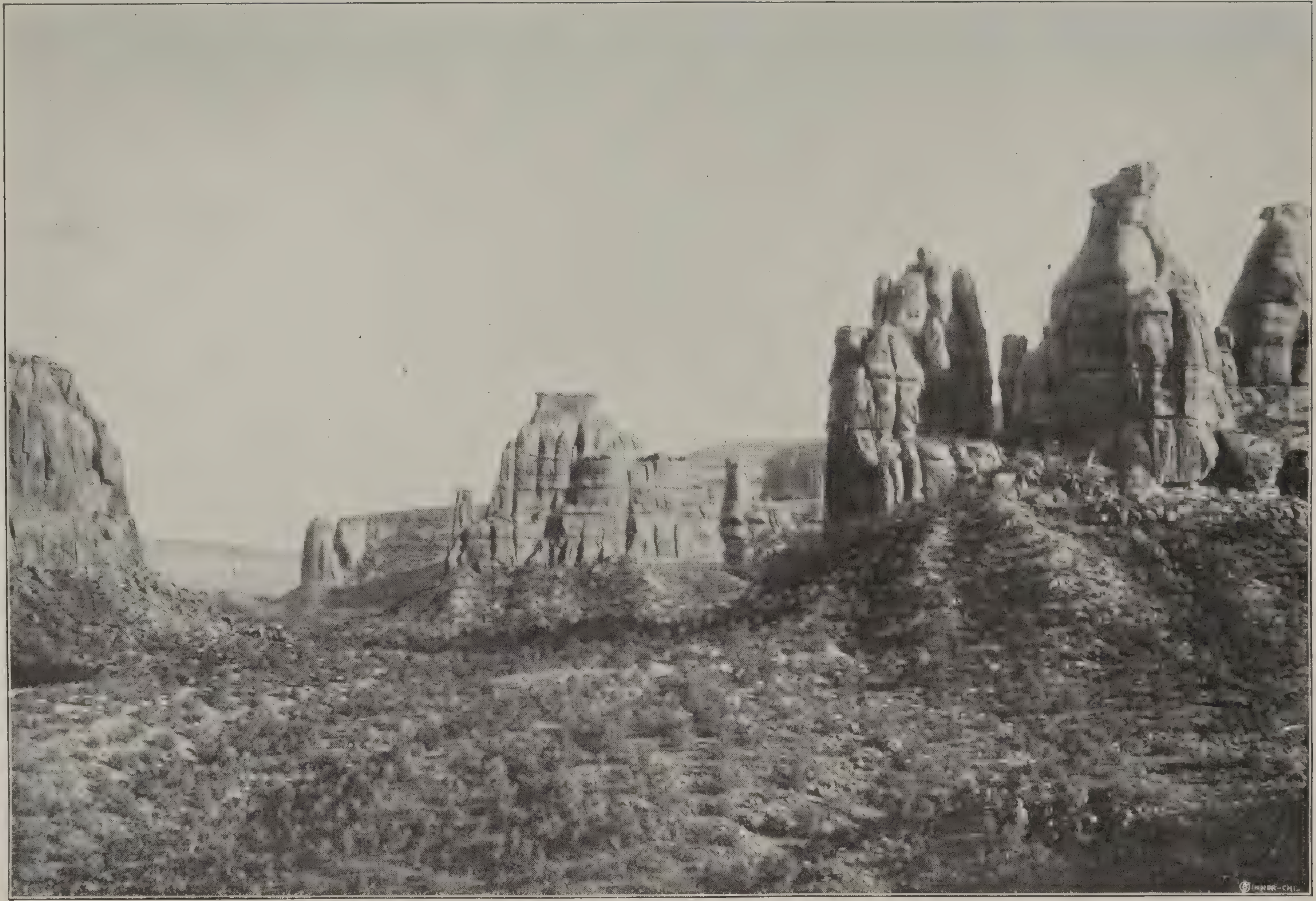
Monoclinal fold in Triassic sandstone broken at the crest.


BINNER-CHI.

LIBRARY
OF THE
UNIVERSITY OF ILLINOIS

EXPLANATION OF PLATE XXXVII.

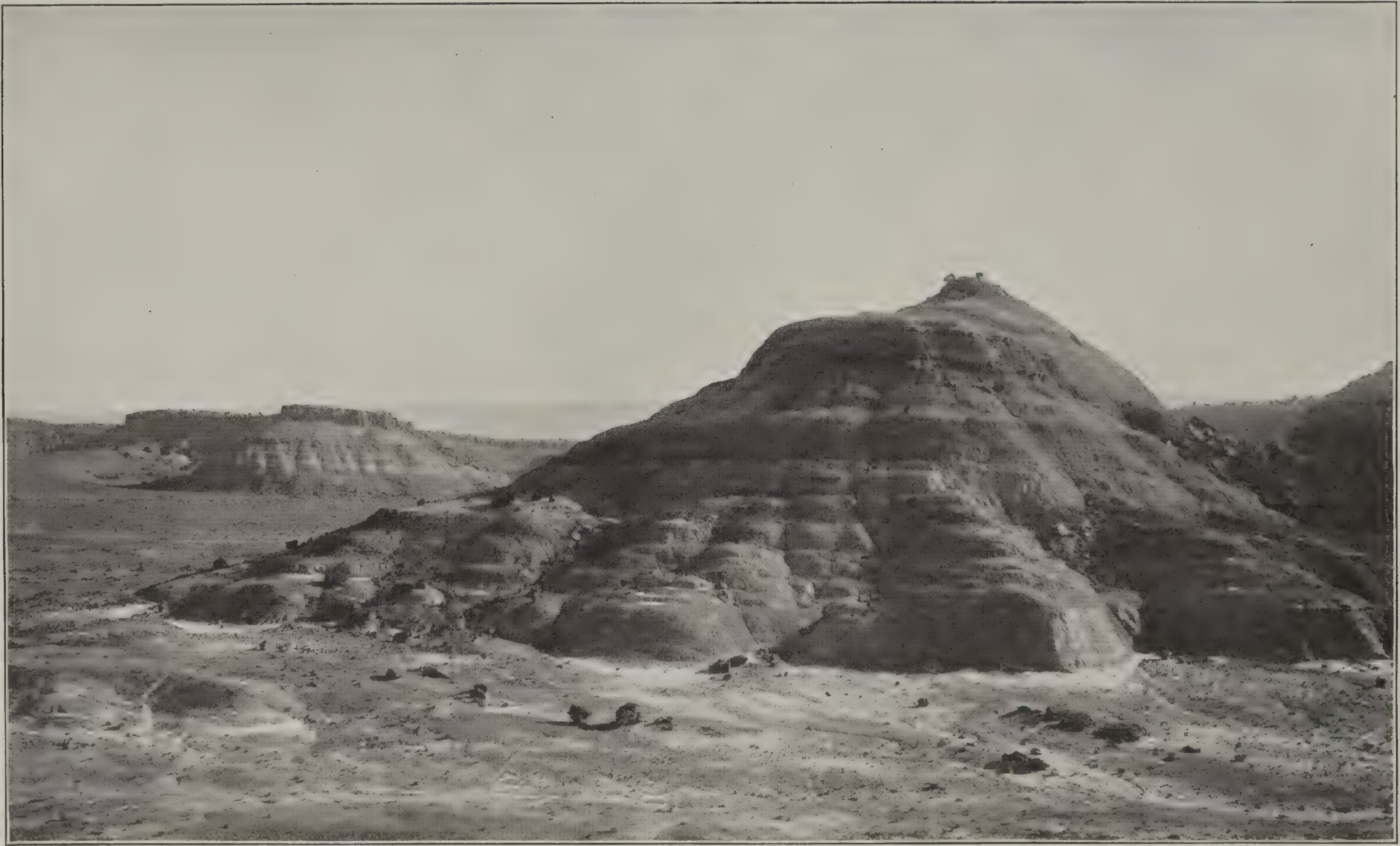
Fantastic weathering of Triassic sandstone as exposed in Monument Park. The underlying granite appears in the foreground.



LIBRARY
OF THE
UNIVERSITY OF ILLINOIS

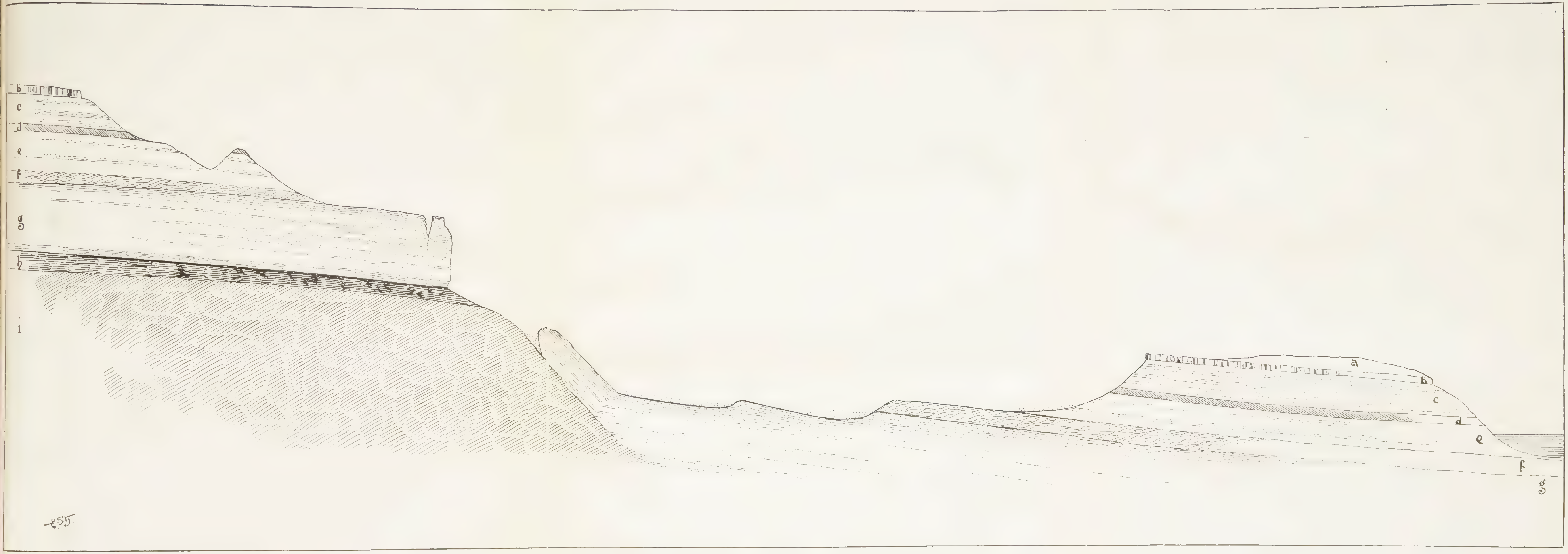
EXPLANATION OF PLATE XXXVIII.

Bad-land weathering in variegated Jurassic clays, with typical butte capped with Dakota sandstone appearing in the distance.



LIBRARY
OF THE
UNIVERSITY of ILLINOIS.

LIBRARY
OF THE
UNIVERSITY OF ILLINOIS



Cross Section of Grand River Valley from the Crest of Red Mesa to the River Bed.

a. Colorado group (Cretaceous).
b. Dakota sandstone (Cretaceous).
c. Variegated clays (Jurassic).
d. Cross-bedded sandstone (Jurassic).
e. Green shales (Jurassic).
f. Marine beds (Jurassic).
g. Red sandstone (Triassic).
h. Vermilion shale (Triassic).
i. Intrusive granite.

FIELD COLUMBIAN MUSEUM
PUBLICATION 63.
GEOLOGICAL SERIES. VOL. I, NO. 10.

THE FORE LEG AND PECTORAL GIRDLE OF MOROSAURUS

WITH A NOTE ON THE GENUS CAMAROSAURUS

BY

ELMER S. RIGGS,
Assistant Curator, Department of Geology.

OLIVER CUMMINGS FARRINGTON, PH.D.,
Curator, Department of Geology.

CHICAGO, U. S. A.
October, 1901.

THE FORE LEG AND PECTORAL GIRDLE OF MOROSAURUS.

BY E. S. RIGGS.

The genus *Morosaurus** Marsh, is based upon a sacrum offering for its primary distinguishing character the presence of four coössified centra. Other distinguishing characteristics are the massiveness of the anterior portion of the skull and mandible, the expansion of the upper end of the scapula, the broad blade of the ischium and the posterior direction of its distal end. The sutural articulation of the neural arch with the centrum in the vertebræ is not significant but dependent upon age.

Marsh has proposed five species under this genus: *M. grandis*, *M. impar*, *M. robustus*, *M. lentus* and *M. agilis*. Of these species he offers but few distinctive characteristics and in his monograph makes no attempt to distinguish them. *M. impar* was the type of the genus, but, as Williston has already pointed out,† it is clearly a synonym of *M. grandis* earlier described as *Apatosaurus grandis*. While the specimen upon which the former species was based must remain the generic type, that of the latter being much more complete and better known will naturally be referred to in comparisons. *M. robustus* is based upon a lone ilium larger than the last, but otherwise difficult to identify. *M. lentus* is not to be distinguished by the sutural articulation between the centrum and the neural arch of the vertebræ as Marsh's figures would suggest, but by the massiveness of all parts of the skeleton and the depression of the vertebral pedicles so that the neural arch rests directly upon the centrum. The suture is noticeable in young specimens of other species and evidently disappears in the adult. *M. agilis*, in direct contrast with the last named species, is characterized by the lightness and slenderness of its skeleton and by its very small size. In the hind foot the first digit is massive while the other four are unusually slender.

The genus *Morosaurus* is represented in the collections of this Museum by a nearly complete fore leg with coraco-scapula, two other coraco-scapulæ, an incomplete fore foot, a disarticulated sacrum, an ilium, a tibia and various dorsal and caudal vertebræ, together with a fine series of cervical and dorsal vertebræ not yet removed from the matrix.

---

*American Journal of Science, 3d ser. Vol. XV, p. 242.

†Kan. Univ. Quarterly, Vol. VII, p. 173.

An almost complete fore leg (Plate XL), collected by the Museum expedition of 1900 near Fruita, Colorado, shows some interesting characteristics not hitherto pointed out. The specimen was found in the uppermost stratum of the green shale which represents the lower Como Beds in this locality.* Its dimensions are a little greater than those of *M. grandis*, Marsh, but the proportions are so nearly the same that it seems desirable to refer it to that species. The entire specimen save the foot bones had been weathered out of the matrix and certain parts lost entirely, but its chalcedony filling had preserved the fragments so well that the whole has been restored with approximate accuracy.

The chief point of interest is in the foot-structure which does not agree with the mesaxonic theory of the structure of the front foot in Sauropoda as advanced by Osborn.* On the contrary the first digit in this specimen bears a stout claw which is directed inward and shows evidence of having been semi-opposable. A second specimen belonging to a smaller species has a similar structure.

Of the carpal bones only the radiale is preserved in this specimen (Pl. XLI, Fig. 1). Metacarpal I is not so stout in proportion as that of *Brontosaurus*, but is stronger and noticeably shorter than the succeeding members of the series. Its proximal end presents to the radiale a broad ovoid surface with the long diameter directed meso-anteriorly. The shaft is twisted so that the axis of the distal end is rotated inward. Its articular surface for the first phalanx slopes upward and backward from the anterior to the postero-internal border. Phalanx 1 of this digit is short and prismatic, articulating closely with the carpal as well as with the stout ungual which it bears. The digit as a whole is thus directed mesially with the ungual inclined backward, and as before stated was probably semi-opposable.

Metacarpal II is longer but almost as stout as the first. Its proximal end is broadest meso-laterally while the axis of the distal end is rotated slightly toward the mesial side. Phalanx 1 is very unlike its homologue of the first digit. It is flattened vertically and articulates with the metacarpal by an almost plane surface, while the distal facet is convex and flanked on either side by rugosities for ligamentary attachment. Phalanx 2 is similar in form but smaller and less roughened. The ungual is wanting. Metacarpal III is represented by its distal third only. Metacarpal IV has a constricted proximal end and is more slender in the shaft than Metacarpal V. The latter has a conspicuous process for ligamentary attachment on the posterior angle of its proximal end. A doubtful phalanx, identical in structure with that placed upon Digit I in Am. Mus. No. 332 (*loc. cit.*) has been provisionally referred to Digit V. Its rounded distal end with no trace of articulating surface indicates that it was surmounted by a cartilaginous pad. The phalanges belonging to Digits III and IV have been lost, so that their formula can not be determined from this specimen. The gradation in size of the metacarpals from I to IV as well as the mesial inclination of the distal axes of I and II offers further evidence that Marsh was right in placing the larger unguals on the first digits in this genus.

---

*Riggs, Dinosaur Beds of the Grand River Valley of Colorado, Pubs. Field Columbian Museum, Geological series, Vol. I, No. 9.

†Bulletin of the American Museum, Vol. XII, p. 168.

An incomplete foot (Pl. XLI, Fig. 2), found by the writer in position, confirms the structure of Digit I. This specimen belongs to a smaller and more slender species than the last described and in the metacarpal region is very similar to the American Museum specimen before cited. The carpals and metacarpals were preserved in their normal positions with Digit I complete and closely connected. The first phalanges of Digits II and III were also in position; those of IV and V were exposed and had been displaced. In this specimen, as in Mus. No. 6668, Digit I is the strongest of the series and is armed with a stout claw. Phalanx 1 of this digit has the same angular form common to this bone in both the front and hind feet of Sauropoda. Its close articulation with the carpal by a well-marked concave surface, together with the stout ungual which it bears, indicates the important function laid upon this digit. The digit as a whole was directed inward and forward, showing no indication of having been opposable, as in the larger form.

The metacarpals grade evenly in size from the first to the fourth; the fifth is about as strong as the second. In length there is a noticeable tendency toward symmetry in the series. The first and fifth are nearly equal, as are the second and third; the fourth is intermediate. On the postero-lateral angle of Metacarpal II there is a strong process for ligamentary attachment. The first phalanges of Digits II and III are compressed vertically and laterally constricted at the middle. There is nothing in the structure of this foot to warrant placing it in the genus *Morosaurus* save its similarity to the foot of the American Museum specimen No. 332, which is associated with a scapula of the Morosaur type. From foot structure alone it could scarcely be included in the same genus with the larger species just described.

The scapula and coracoid of No. 6668 are firmly coössified, as is true of the two other specimens of this genus which will be noticed. Compared with *Morosaurus grandis*, Marsh, the scapula as a whole is a little larger and the neck slightly longer in proportion. The coracoid is somewhat larger owing to the ossification of the connecting cartilage.

The humerus is a little shorter in proportion to the scapula and fore-arm and the deltoid crest is more prominent than shown in the type. However, the two bones are crushed in different directions, which probably accounts for apparent differences. The ulna is stout at the proximal end and deeply concave on the anterior surface to receive the radius. It is stronger in the shaft than the latter, but tapers so that the distal ends are about equal in size. The radius is nearly uniform in the shaft; the proximal end is more rounded and but little larger than the distal end. The radius crosses from the front to the side of the ulna; its angular surface admits of little or no rotary motion.

Following are a series of measurements of the fore leg of Museum specimen No. 6668 compared with measurements made by the writer from the type specimen of *M. grandis* preserved in the Museum of Yale University:

	No. 6668. M.	Type, *M. grandis.* M.
Coraco-scapula, total length with curve, ...	1.575	. . . .
Scapula, total length with curve, ...	1.215	1.093
Scapula, length of upper end from concave border of blade, ...	.665	. . . .
Scapula, greatest breadth of blade, ...	.590	.635
Scapula, greatest breadth of upper end, ...	.384	. . . .
Scapula, least breadth at constriction, ...	.190	. . . .
Coracoid, greatest breadth, ...	.535	. . . .
Coracoid, breadth from suture to inferior border, .	.330	. . . .
Humerus, length, ...	.970	.864
Humerus, breadth at proximal end, ...	.390	.381
Humerus, breadth at distal end, ...	.285	.260
Humerus, breadth of shaft at middle, ...	.135	.127
Humerus, distal end to inferior margin of deltoid crest, ...	.485	. . . .
Ulna, length, ...	.705	.628
Ulna, greatest breadth proximal end, ...	.242	. . . .
Ulna, greatest breadth distal end, ...	.137	. . . .
Radius, length, ...	.665	. . . .
Metacarpal I, length, ...	.207	. . . .
Metacarpal II, length, ...	.243	. . . .
Metacarpal V, length, ...	.228	. . . .
Ungual, Digit I, length, ...	.188	. . . .

Measurements of foot, Mus. No. 6641, compared with published measurements of the American Museum specimen No. 332 are as follows:

	No. 6641. M.	Am. Mus. No. 332. M.
Length of Metacarpal I,	.250	.205
Length of Metacarpal II,	.288	.250
Length of Metacarpal III,	.285	.250
Length of Metacarpal IV,	.260	.235
Length of Metacarpal V,	.245	.205
Length of Ungual, Digit I,	.140	....

A second coraco-scapula of considerably smaller size is even more distinctly of the Morosaur type (Pl. XLII, Fig. 1). It was also collected by the Museum Expedition of 1900 from the upper Como beds of the Grand River Valley, but came from a horizon fully one hundred feet above that of No. 6668. The specimen is splendidly preserved, as the photograph shows, and is complete in outline save a small portion of the upper end, which was distorted by crushing. The two bones are firmly ankylosed at the coraco-scapular suture and bear every evidence of having belonged to an animal fully adult. Its form as well as that of associated vertebræ at once identifies it with *M. grandis.*

The blade of the scapula is somewhat broader in proportion and the neck shorter than that of the type specimen. The superior margin of the blade is produced into a hook so thin as to be usually broken away and lost, but it has been observed in other well-preserved specimens. The postero-inferior border at the constriction is likewise produced into a thin prominence. The coracoid is proportionately larger and its junction with the scapula is marked by only a slight indentation in the superior border. The opening of the foramen on the lateral surface is directed downward in line with the scapular axis. An anterior view (Pl. XLII, Fig. 2) shows the natural curve of the scapula as well as that of the coracoid. The curve formed by their junction has been much reduced by crushing, as the opening of the suture on the mesial surface shows. A fine series of cervical and dorsal vertebræ, belonging to this specimen but still in the matrix, may add important data to our knowledge of the vertebral column in this genus.

Measurements of coraco-scapula, No. 6670:

	M.
Coraco-scapula, total length with curve,	1.405
Scapula, length with curve,	1.045
Scapula, greatest breadth of blade,	.625

	M.
Scapula, greatest breadth of upper end,	.855
Scapula, least breadth at constriction,	.185
Coracoid, greatest breadth,	.432
Coracoid, breadth from suture to inferior border,	.343

A much larger species of *Morosaurus* is represented by a well preserved coraco-scapula, a tibia, an ilium and a number of caudal vertebræ in the Museum collection, and a femur and fibula, in the collections of Kansas University, all from the Freeze-out Hills of Wyoming. The scapula and coracoid are firmly coössified (Pl. XLII, Fig. 3). The former is longer in proportion to its breadth than any other specimen of this genus examined. In outline the blade is rounded at the antero-superior border and with the coracoid forms a deep notch at the suture. The coracoid is likewise rounded in outline from the suture to the lip of the glenoid cavity and is deeply concave on the mesial surface.

Owing to the fact that this specimen was found in a general deposit where members of several species were heterogeneously associated, it is impossible to determine all of the parts belonging to this individual. The parts of the front and hind legs known show that they belonged to an animal much larger than any Morosaur yet described. But as it is not desirable to further encumber the literature with useless synonyms, this specimen will be provisionally referred to *M. robustus.*

It is noticeable in the coraco-scapulæ of this genus that the smaller adult specimens are broader in proportion and have their upper ends less produced. With regard to these proportions, it may be said that they grade quite evenly from the smallest to the largest specimen described. It is also worthy of note that of the three coraco-scapulæ figured, all are coössified. While this cannot be regarded as indicating anything more than adult age, it does indicate that coössification of the scapula and coracoid is common in the adult of this genus. A considerable variation in the outlines of the two bones in the region of the articulating border may thus be accounted for. In the young animal the coracoid is rounded at the angles; with the ossification of the connecting cartilage these fill in until there is but little indentation of the blade at the sutural line. By this process the coracoid not only increases in size, but the antero-superior angle becomes more produced.

NOTE ON THE GENUS CAMAROSAURUS, COPE.

While examining the type specimen of *Camarosaurus* at the American Museum, through the kindness of Dr. Osborn, the writer was struck by the similarity of its pectoral girdle to that of *Morosaurus*. This similarity is especially noticeable between the large coracoscapula (Mus. No. 6285) and Cope's type as figured in Pl. XLII. The presence of but four coössified centra in the sacrum offers a further basis of correlation. The gap between the two forms, in point of size, is now partially bridged by the large specimen just referred to, *M. robustus*. *Camarosaurus* may thus prove to be the extreme type of development in this phylum; if not, as Dr. Osborn has suggested,* a member of that genus.

However, it is probable that *Atlantosaurus*, Marsh, is more nearly related to this genus than is *Morosaurus*. The types of both come from the same locality at Cañon City and from nearly the same horizon. Their size, as represented by the length of the femora, is essentially the same. Each has four coössified centra in the sacrum; those of the Cope specimen are described as solid, while the New Haven specimen is nearly so. A third sacrum in the collection of this Museum, provisionally referred to Atlantosaurus,† has the same vertebral formula, is similar in relative size and has only very small cavities in the centra. The coracoid of the Museum specimen is similar to that of the type, though slightly larger, as is the specimen throughout. The characters of the first caudal, especially the short blunt diapophyses, are characteristic of both. In his original description Cope predicted the unusually long humerus which the Museum specimen has so well demonstrated. The three specimens may thus be regarded as representatives of a single genus, which, in view of its priority, should retain the generic name *Camarosaurus*. The description of the type specimen promised by Dr. Osborn will doubtless throw further light upon the relationship of this interesting group.

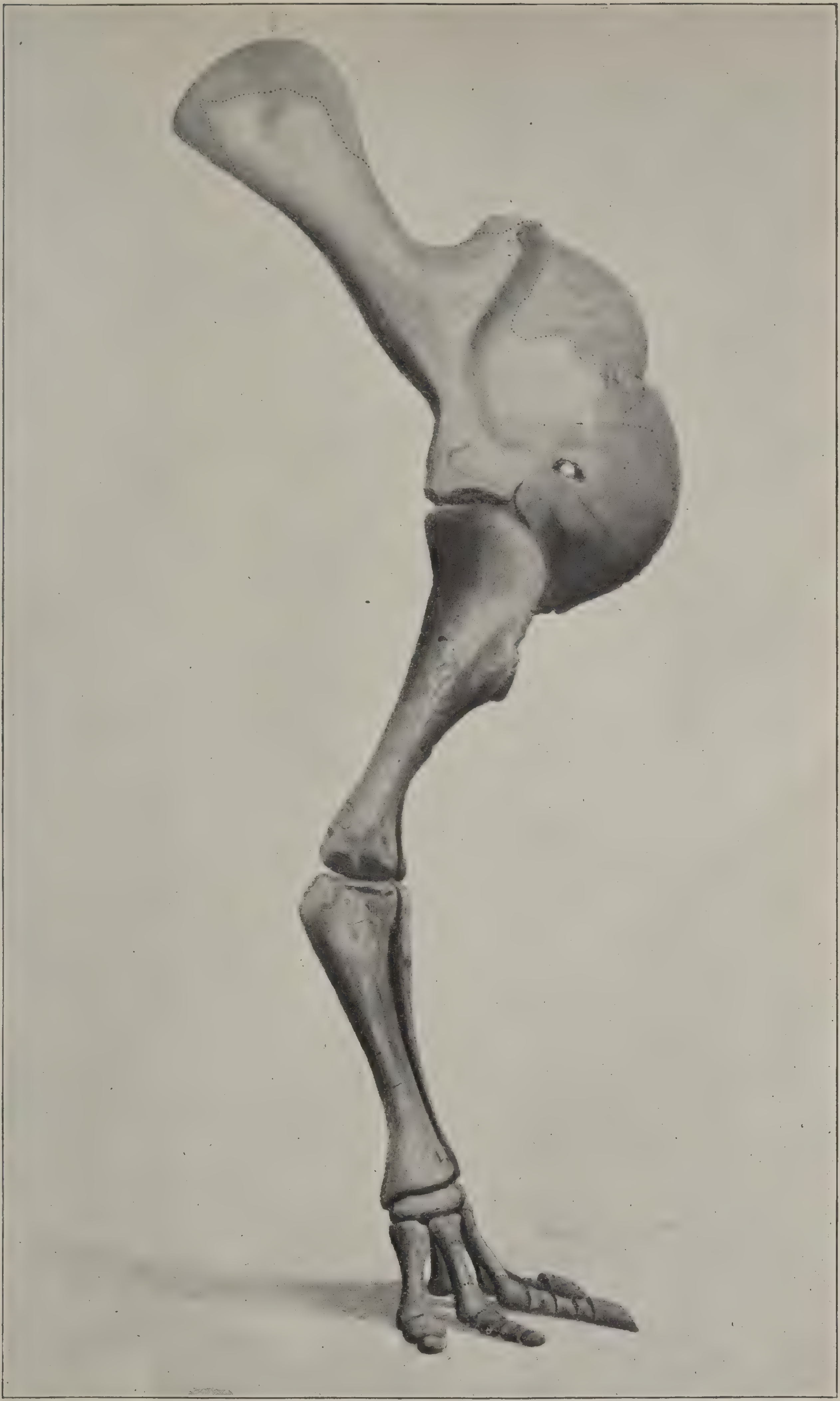
---

*Bull., Am. Mus., Vol. XIV, p. 200.

†Science, April 5, 1901.

EXPLANATION OF PLATE XL.

Right fore leg of *Morosaurus grandis*. Mus. No. 6668, × $\frac{1}{16}$.



LIBRARY
OF THE
UNIVERSITY OF ILLINOIS

Explanation of Plate XLI.

Fig. 1. Fore foot of *Morosaurus grandis*. Mus. No. 6668, $\times \frac{1}{6}$.
Fig. 2. Fore foot of *Morosaurus sp*. Mus. No. 6641, $\times \frac{1}{6}$.
X indicates restored parts.

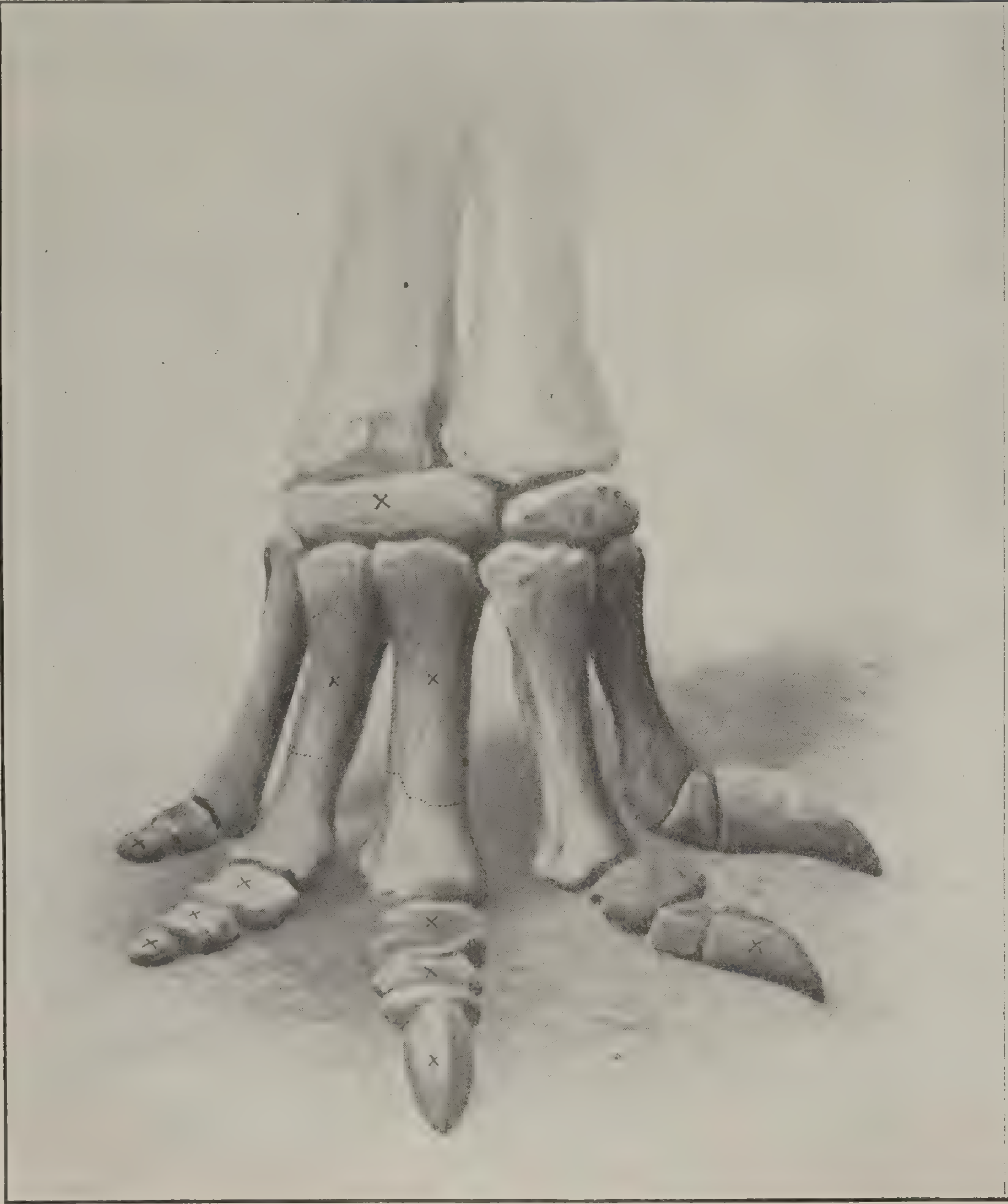


FIG. 1.

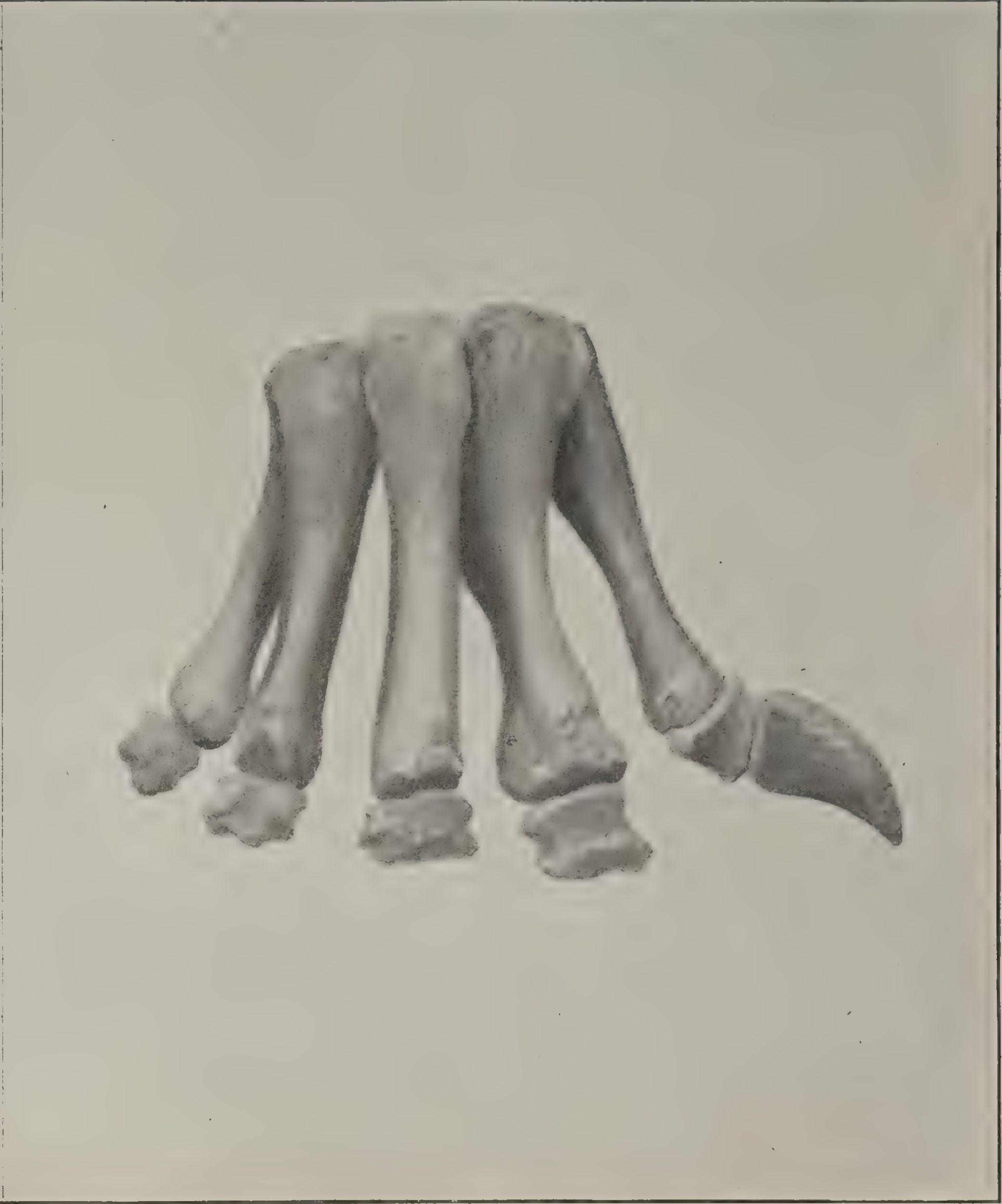


FIG. 2.

LIBRARY
OF THE
UNIVERSITY of ILLINOIS

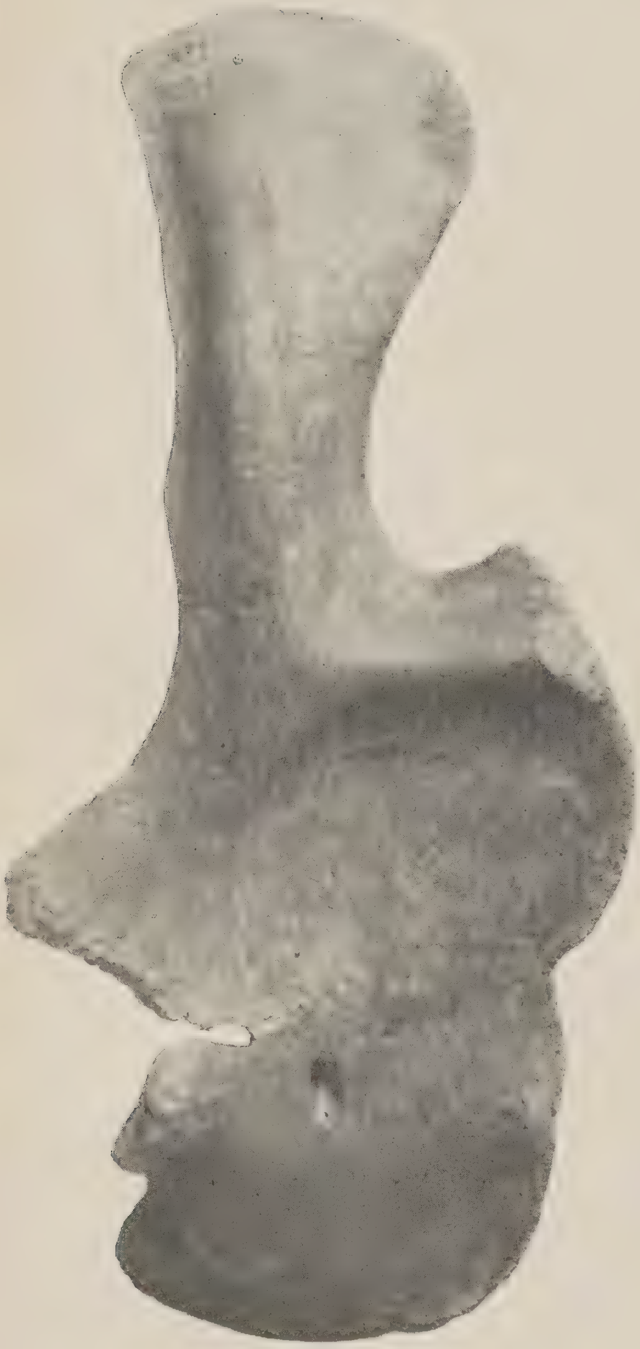


FIG. 1.

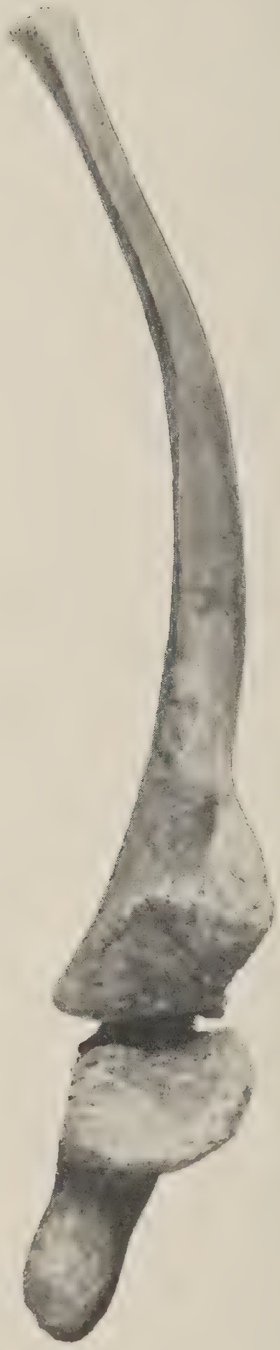


FIG. 2.

Fig. 1. Right coraco-scapula of *Morosaurus grandis.* Mus. No. 6670.
Fig. 2. Anterior view of the same.

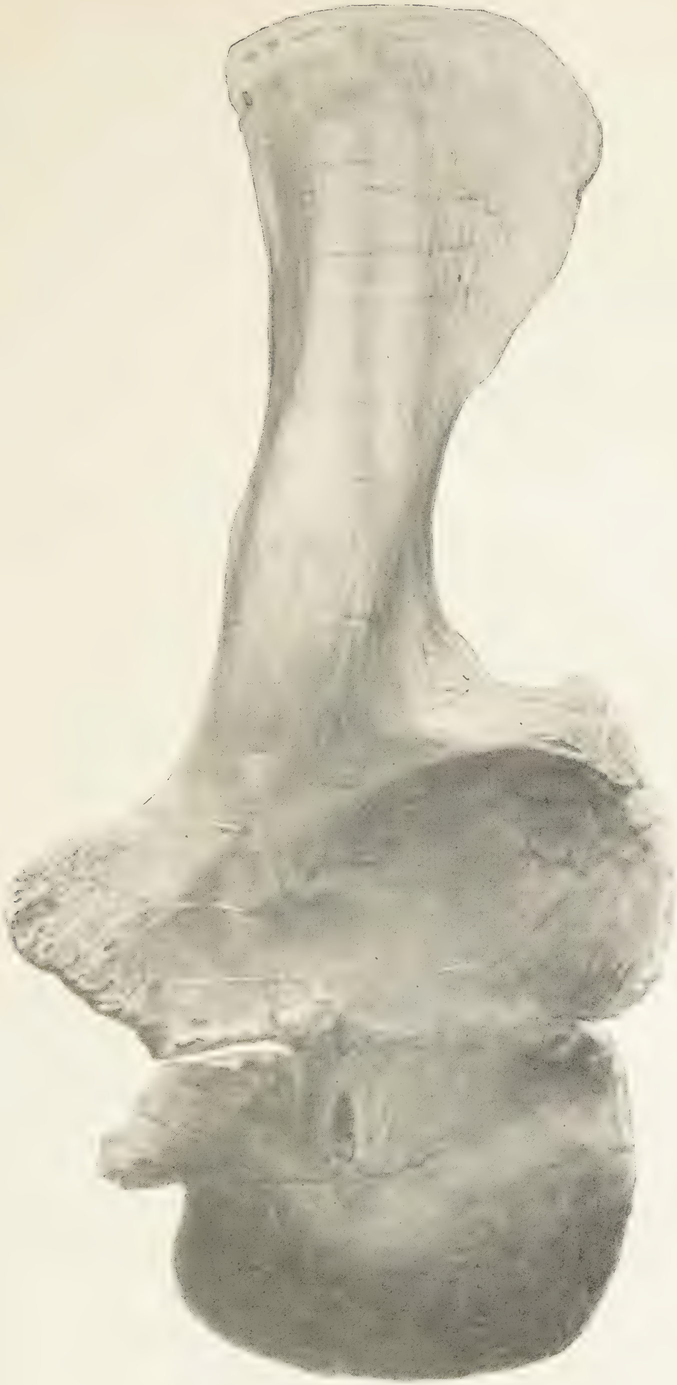


FIG. 3.

Fig. 3. Left coraco-scapula (reversed) of *M. robustus*. Mus. No. 6285.

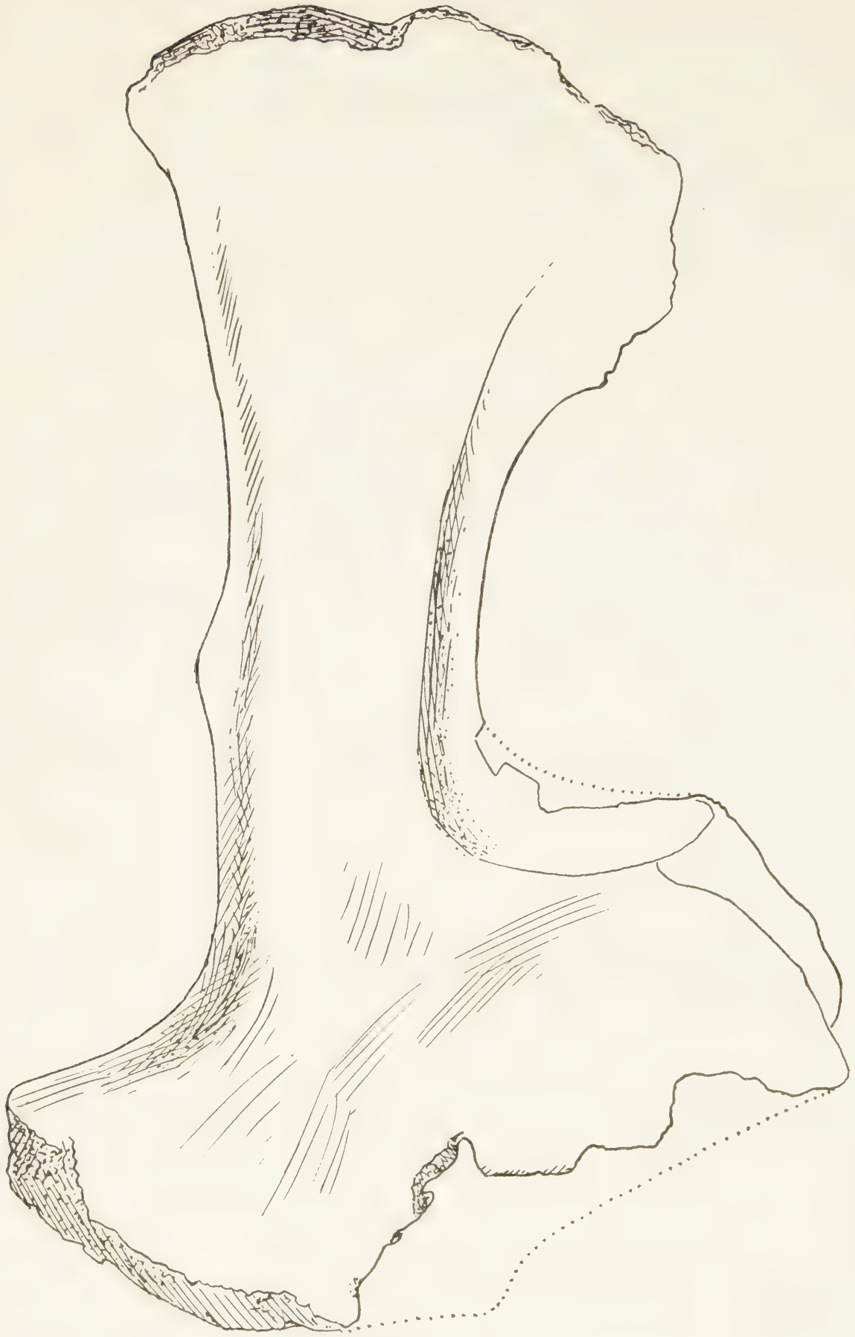
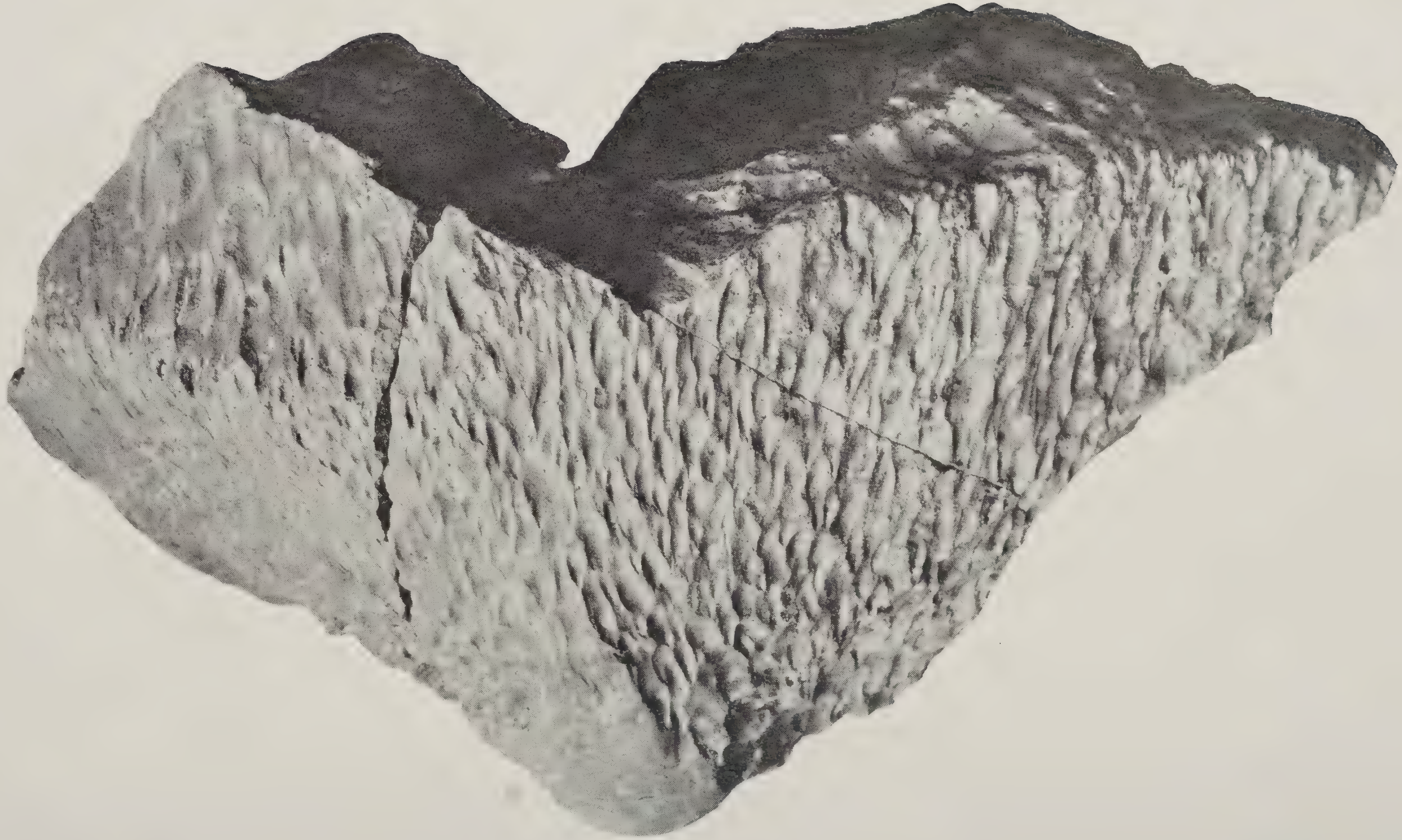


FIG. 4.

Fig. 4. Right scapula of *Camarosaurus supremus*, from Cope's figure, Bull. 25, Proc. Phil. Acad. Sc.

All × $\frac{1}{11}$.

LIBRARY
OF THE
UNIVERSITY of ILLINOIS



FRONTISPIECE.

EXPLANATION OF PLATE XLIII.

Long Island meteorite as at present restored. × $\frac{1}{5}$.

From a photograph. The position from left to right of the page is that probably assumed by the meteorite in falling.

FIELD COLUMBIAN MUSEUM
PUBLICATION 64.
GEOLOGICAL SERIES. VOL. I, NO. 11.

METEORITE STUDIES—I.

BY

OLIVER CUMMINGS FARRINGTON, Ph. D.
Curator, Department of Geology.

CHICAGO, U. S. A.
May, 1902.

METEORITE STUDIES—I.

BY OLIVER CUMMINGS FARRINGTON.

LONG ISLAND, PHILLIPS COUNTY, KANSAS.

MUSEUM NUMBER Me. 420.

Nearly all of this great meteorite is possessed by the Museum and this has been the case since the opening of the institution in June, 1894, but it has never been fully described. A few lines were devoted to the meteorite and a cut of it shown in the catalogue of the meteorite collection published in August, 1895.* A petrographic description from fragments of the stone was also given by E. Weinschenk in 1895.†

No account of the finding of the stone seems ever to have been published however and there are many other features which are well worthy of description. For details regarding the occurrence of the stone I am indebted to Prof. Williston of the University of Kansas and Prof. Willard of the Kansas Agricultural College. Prof. Williston states that a fragment of the meteorite first reached him in the fall of 1892. Prof. Willard secured one at about the same time. On recognizing the meteoritic nature of the fragments sent them, Profs. Williston and Willard at once entered upon negotiations for the purchase of the mass and soon became its possessors. The work of collecting the pieces at the original locality was done by Prof. Willard, and to him I am indebted for information regarding the occurrence there.

The meteorite lay, he states, on a slope of the ordinary soil of the upland prairie region. There is no outcrop of rock in the immediate vicinity and none within several miles, so far as he knows. Where there is an outcrop the rock is limestone. The distribution of the pieces of the meteorite as first seen by Prof. Willard was such as to indicate that the mass had struck upon the slope and its front portion being stopped, the rear portion had broken up and gone ahead. The four large pieces which are put together to make the mass shown in

---

* Field Columbian Museum Publication 3, p. 59.

† Tsch. Min. u. Petr. Mitth., Vol. 14, p. 471.

Plate XLIII (Frontispiece) were together and in contact at the upper end of the fall. The top of these projected about four inches above the soil and the lowest point to which they reached was perhaps two feet below the surface. Beside these large pieces a quantity of smaller fragments more or less imbedded in the ground extended down the slope in a northwest direction for a distance of from 15 to 20 feet in a gourd-shaped area which was perhaps six feet wide at the widest point. The accompanying section and plan (Fig. 1) from a sketch by Prof. Willard will give an approximate idea of the manner in which the fragments lay. The location of the spot where the meteorite was found is about three miles west of the present town of Long Island, one-half mile east of the west line of Phillips County and three miles south of the Kansas-Nebraska State line. It is from the neighboring town of Long Island that the meteorite takes its name. With regard to the time of the fall no knowledge has yet been obtained. The stone was noticed by early comers to the region and was generally reputed to be a meteorite, so that visitors had in many cases taken away pieces as curiosities. That the mass had lain a number of years in place is proved by the coating of carbonate of lime, in some places two or three millimeters in thickness, which encrusts many of the pieces. Further evidence of the long exposure of the stone is given by the weathered character and rusty brown color of the surface of exposed fragments of the stone in contrast to the dark green color of their interior. The meteorite as collected by Prof. Willard was

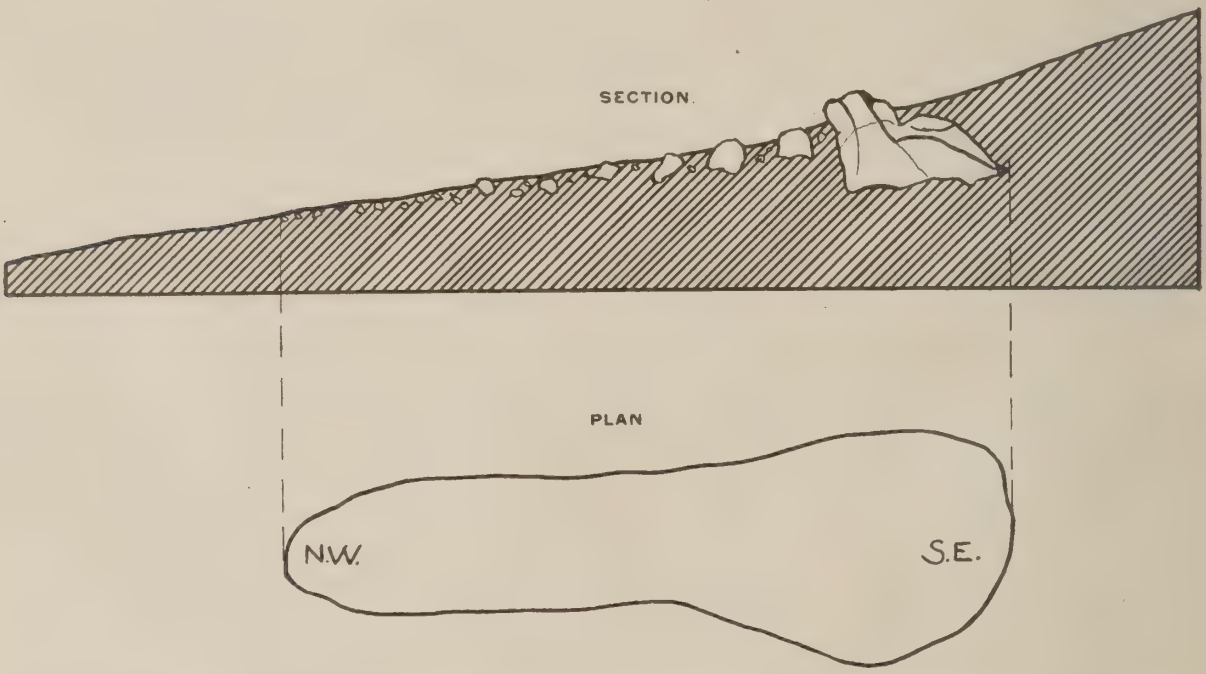


FIG. 1. Section and plan showing nature of occurrence in place of the Long Island meteorite.

shortly afterward purchased by Mr. George F. Kunz, of New York City, and after remaining in his possession for about a year was secured for this Museum.

The entire weight of the meteorite as received at the Museum and made up of 4 large and 2,930 small fragments, was 1,184 pounds (537 kilos). This was supposed at the time to be the entire weight of the mass, but a year or two later Mr. Kunz obtained about 60 pounds (27 kilos) more, which is for the most part still in his possession. This additional material was chiefly fragments obtained from people in the region who had carried off portions of the stone for curiosities. A weight of at least 1,244 pounds (564 kilos) can therefore be positively assigned the stone and there is little doubt that it originally weighed somewhat more than this since some pieces were probably carried off that will never be recovered. That the fragments all belonged to a single mass the manner of their occurrence in place leaves no doubt. Moreover their edges show no rounding or fusing as would have been the case had any of them made an independent passage through any considerable part of the earth's atmosphere. The stone is therefore much the largest single stone meteorite known to exist, its nearest competitors being the Bjurböle meteorite, which weighs 748 pounds (340 kilos) and one of the stones of the Knyahinya fall, which weighs 649 pounds (295 kilos).

As soon as the installation of the stone was undertaken at the Museum, it was at once seen that the four large pieces fitted together. When this was done the form shown in Plate XLIII (Frontispiece) was produced. Doubtless others of the fragments could be added to these, but as an effort to do this proved on trial to be likely to consume considerable time without giving any important results, the attempt was abandoned. There would be more hope of success if the Museum possessed the entire mass of the stone, but as it is, many of the fragments would be missing at best. The four large pieces weigh together 669 pounds (303 kilos), or more than half the weight of the stone. They hence probably give its essential form. Their weights are 269, 239, 89½ and 71½ pounds (122, 108, 46 and 32 kilos) respectively. The largest of the remaining fragments at the Museum weighs 22¼ pounds (10 kilos), which is a weight much below that of the smallest of the four large ones. Mr. Kunz informs me that one of the fragments in his possession weighs about 35 pounds (15.8 kilos). The smaller fragments range from the weight above mentioned to those not over a gram in weight. Some have the true meteorite crust on one surface, showing that they are from the superficial portion of the stone, while the rough, irregular surfaces of the remaining fragments show that they were wholly within the interior. The portion of the stone to which these fragments would be attached if a complete restoration of its form could be made would be that to the rear and to the left of the part shown in Plate XLIII (Frontispiece) or to the rear of the stone in the position in which it is shown in Fig. 1, Plate XLIV. As will be seen by referring to Plate XLIII (Frontispiece) the portion of the stone to the right of a vertical line drawn through the middle of the plate has an almost wholly natural surface. Over this portion therefore the actual form of the stone is preserved. The form of the stone as at present restored is, as shown by the plate, roughly that of a low cone. The greatest diameter of the base of the cone is 34 inches (86 cm.) and the altitude from base to apex 20 inches (51 cm.) The conical form, as is well known, is the typical one to which meteorites are reduced in their passage through the atmosphere, from the fact that the portion of the mass in front receiving the brunt of the friction and heat is worn down rapidly to an apex from which the other portions slope away. That this is the position which the Long Island stone took in falling is further indicated by the smooth, unpitted character of the base of the cone (*Rückseite*) as compared with the pitted surface of the conical portion, and further by the fact that the series of pittings (*piezoglypten*) on the surface extend in radial directions from the apex of the cone. It will be noted in the plate that the long axes of the pits run in directions nearly parallel to lines drawn from the apex to the base of the cone. These then were the directions of the air currents. The planes along which the four large fragments were separated and along which they have now been joined together are not courses of ordinary irregular fracture, but are definite divisive planes. There are three of these planes, two being continuous each in its own direction while the third may be described as made up of two planes meeting at a very broad angle (160°). The planes run in three directions nearly at right angles to each other. They meet, but only at one point do they pass through one another. If one will conceive of an apple cut in halves by a plane starting a little to one side of the bloom, one of these halves then cut through equatorially in a direction at right angles to the first plane by two planes starting a little above the equator, but meeting at it, then the quarter nearest the bloom cut through by a plane at right angles to the equatorial plane in a direction running from the bloom to the stem, and passing into the otherwise uncut half for quite a distance, an idea will be gained of the course of the division planes of this meteorite. Their course can also be seen by reference to Plate XLIV.

The area of each plane is approximately as follows:

Plane A = 200 sq. in. (13 sq. dm.)
Plane B = 196 sq. in. (12 sq. dm.)
Plane C = 113 sq. in. (7.1 sq. dm.)

The position of these planes makes it unlikely that they were developed by the blow of the meteorite in striking the earth, for one at least runs nearly at right angles to the probable direction of motion of the meteorite. Further, as stated more in detail below, the striæ of the slickensided surfaces run in different directions.

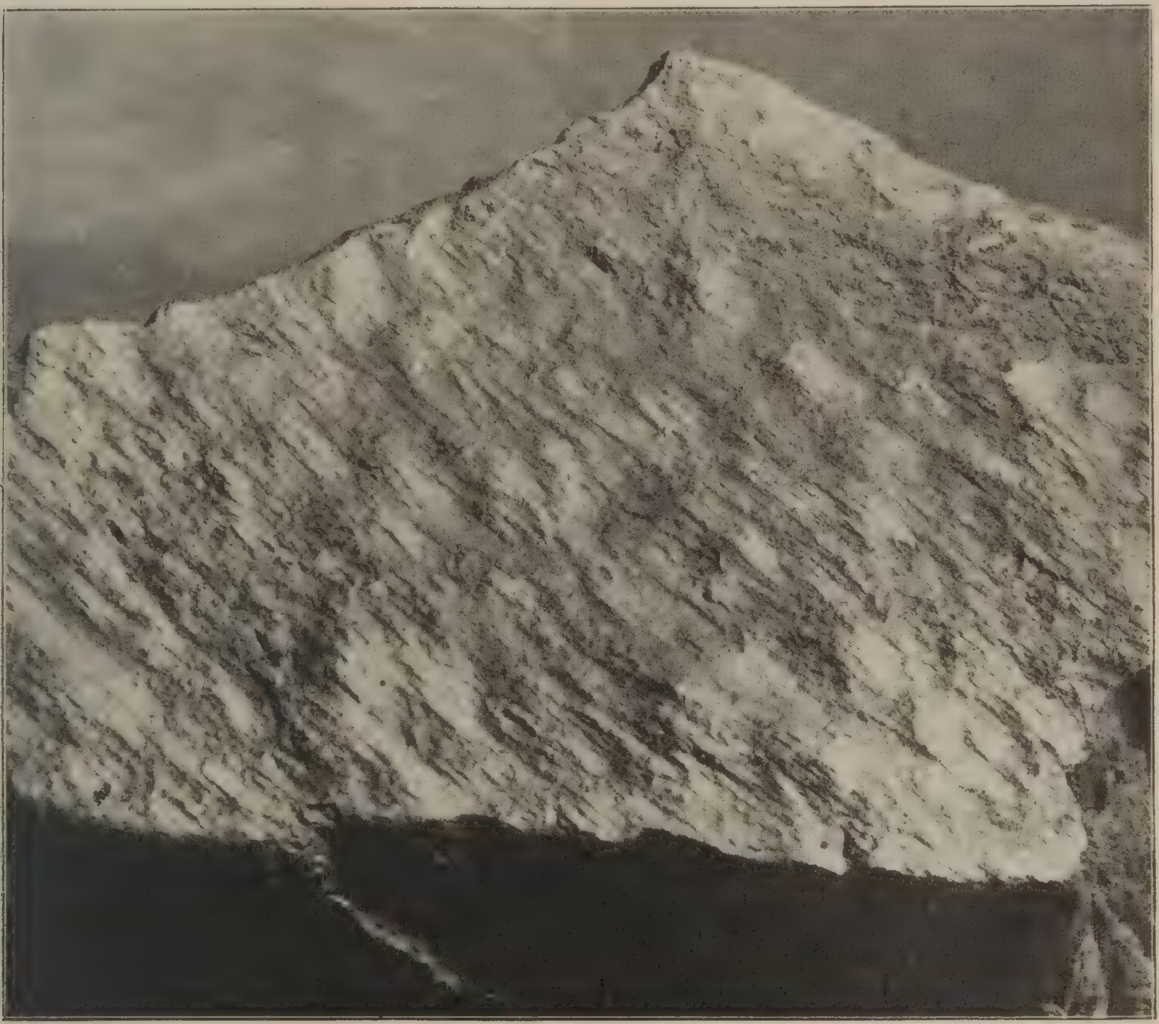


FIG. 2. Slickensided surface of Long Island meteorite. × 1.

The plane marked (A) in Fig. 2, Plate XLIV, runs quite nearly in the direction of probable motion and it is interesting to note that near each end of the meteorite irregular cracks appear which are approximately parallel to this plane. Their position suggests that they may have been produced by the tendency of the base of the meteorite to continue its motion after the apex had been stopped by striking the earth. The plane marked (C) separating Pieces 2 and 4 can be noted continuing on in Piece 1 as a line which extends nearly to the edge of that piece. This portion of the plane evidently was not sufficiently developed as a division plane to produce disruption of the piece when the meteorite struck the earth.

That the three planes described represent a structure which existed in the meteorite before its entry into the earth's atmosphere there can be little doubt. They are too regular to make it possible to consider them planes arising from fracture by shock and there are several other lines of evidence pointing to their preterrestrial existence. The most important of these is that their surfaces are slickensided. The slickensided character of the surface resembles that seen in terrestrial rocks and is illustrated in Fig. 2. It is a smooth, shining, somewhat undulatory, like a *roche moutonnée* surface, and bears short striæ which on the same surface run in one general direction, but take different directions on the three several planes. These several directions are indicated in Plate XLIV, Fig. 2, where one of the fragments is represented as removed. The color of the slickensided surfaces is somewhat darker than that of the crust of the meteorite, but there is no evidence of special heat having been developed by the force which produced the slickensides. This I have tested by cutting sections at right angles to the surfaces. The outlines of the individual grains were found to be sharp and unaltered up to the slickensided edge.

Since slickensided surfaces on terrestrial rocks are so far as known produced by slow differential movement in the mass under considerable pressure and while in the solid state, they may in the absence of any evidence to the contrary be assigned to the same cause in this meteorite. The conclusion seems fair therefore that these planes and surfaces were formed during the preterrestrial existence of the mass and that the mass must have been solid in its nature while in space. The three planes which I have described seem to me to resemble the joint planes of terrestrial rocks more than anything else I can think of and give us grounds for asserting the existence of joint structure in the rocks of space. I do not know that well marked joint structure has been observed in any other meteorites except that noted by Meunier in one of the stones of L'Aigle*. This stone he regarded as possessing a joint fissure, but it was not as well developed as the planes of the Long Island stone.

If the occurrence of joint structure in the Long Island stone is deemed proved, it is significant as pointing to a considerable mass possessed by the body in space. Joint blocks of such size as this would not be likely to be developed in a small body.

---

*Fremy's Encyc. Chimique, Tome II., Meteorites, p. 457.

EXPLANATION OF PLATE XLIV.

Fig. 1. Drawing of restored portion of Long Island meteorite to show position and number of dividing (joint) planes. The position of the meteorite is as if it had been rotated upward from that shown in Plate XLIII, bringing the apex of the cone to the front.

Fig. 2. Drawing of restored portion of Long Island meteorite in slightly different position and with Piece 2 removed, to show direction of striæ on dividing (joint) planes.

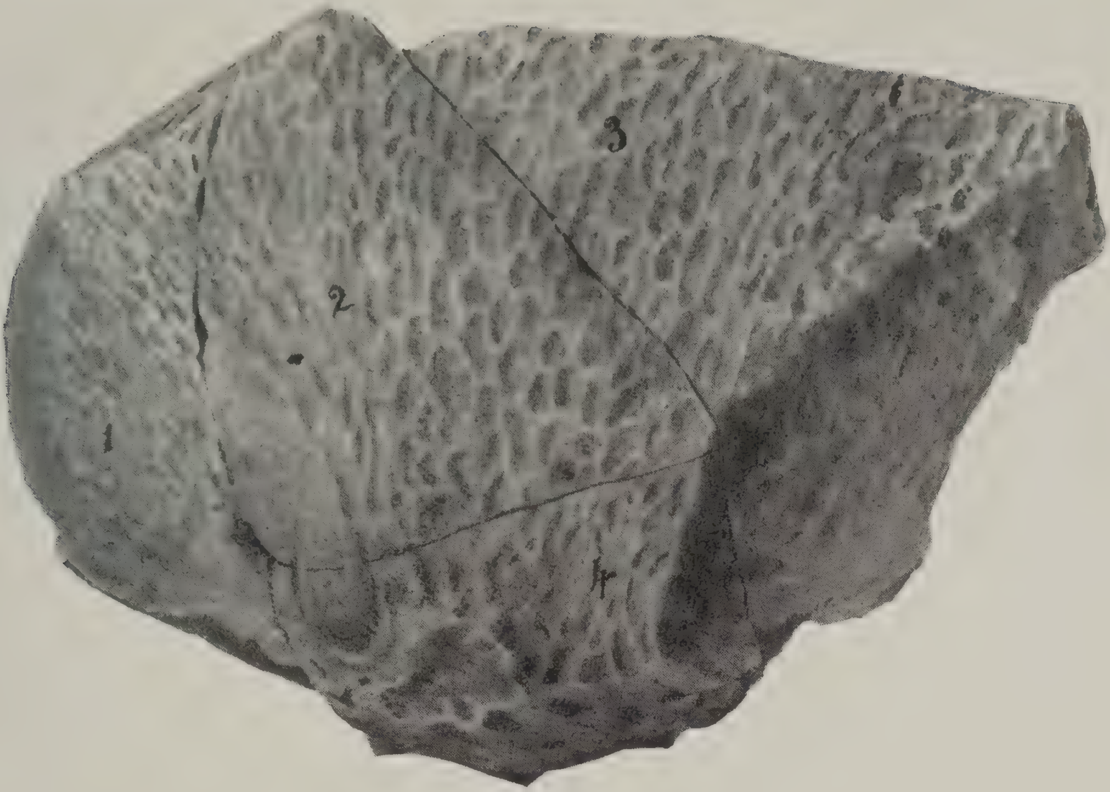


FIG. 1.

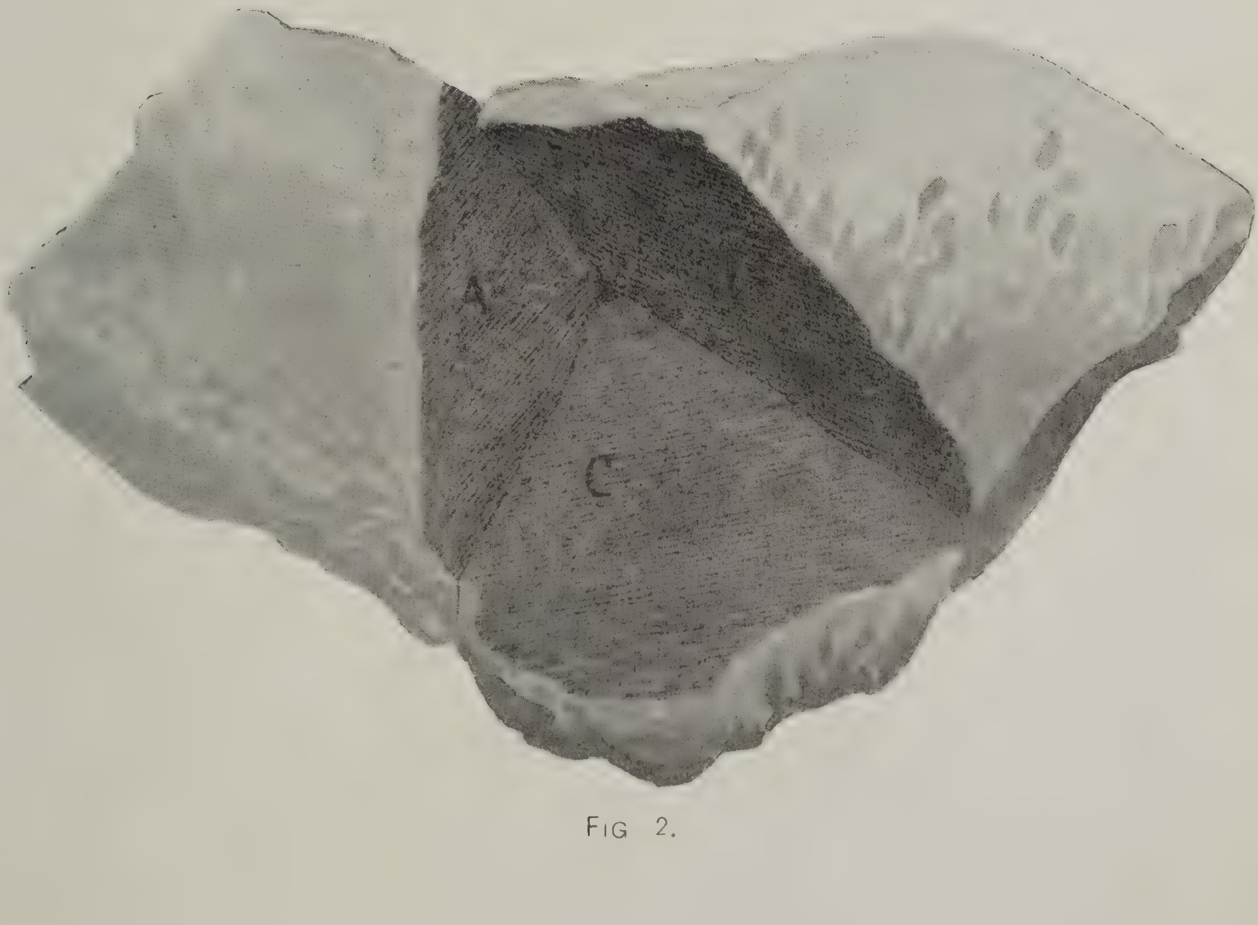


FIG 2.

LIBRARY
OF THE
UNIVERSITY of ILLINOIS.

The natural surface of the more conical part (*Brustseite*) of the meteorite as it is at present joined together, is for the most part deeply pitted with characteristic meteoritic thumb-marks (piezoglypten). These pits vary considerably, as would be expected, in form and size, but still exhibit a certain uniformity. The majority have the form of an elongated ellipse whose major axis is about twice the length of its minor. The following dimensions may be considered as representing a fair average of the size of the pits: Major axis, 3.2 cm. (1¼ in.) Minor axis, 1.5 cm. (⅝ in.) Depth, 3 to 10 mm. (⅛ to ⅜ in.) The depression of each pit generally slopes uniformly toward the center of the ellipse, but often there are to be found pits, the deepest point of which is quite eccentrically placed and which have a more or less conical shape. Some pits have a nearly circular outline as contrasted with the more common ellipsoidal one. These circular pits are usually of small size, but one of large size and unusual depth is to be found at the point in the meteorite where the two planes A and C cut each other. This pit has for the most part the shape of a deep regular bowl, although the regularity of one portion is broken by two smaller conical pits. The depth of this pit is 3.2 cm. (1¼ in.) and its diameter 6.4 cm. (2½ in.) The point of junction of the planes is almost exactly at the center of the pit. It is evident that this was a point of weakness in the stone at which the erosive action of heat and friction produced during the passage of the mass through the atmosphere worked more rapidly than on other parts of the surface. Its occurrence at the point of junction of the planes is pretty good evidence that the latter existed in the stone previous to its entry into the atmosphere. This fact has also a bearing on the disputed question as to the origin of the pits in general. It shows that they owe their origin chiefly to an excavation by heat and pressure of the softer or more friable parts of the surface of the mass which is acted upon. Wherever there is a point of weakness there a pit will be formed. Vice versa, where a pit is formed, there was a point of weakness.

The rear side (*Rückseite*) of the stone is not pitted. It has a well developed crust, but the encrusted surface exhibits no marked depressions or elevations. The only portion of the meteorite as now restored which illustrates the *Rückseite* is that appearing in the upper right hand part of Plate XLIII (Frontispiece). Here the surface is slightly undulating, but there are no pits.

The color of the crust of the meteorite is in general dark brown, but varies from almost black to light brown. At a little distance it appears perfectly smooth and in places shining, but on close examination it is seen to be quite uniformly and coarsely stippled by the protrusion of the more resistant grains. In many places, especially in the vicinity of the pits, minute thread-like markings appear over the surface, sometimes in parallel and concentric series, but more commonly in arborescent forms which are often quite elaborate. These series or systems of markings do not appear to run in any common direction, but are differently oriented wherever found. I have noted no system more than one inch (2.5 cm.) in length, but several of about this extent. They resemble closely the lines of flow such as have been noted on the crust of the Stannern and other meteorites, and doubtless are of this nature, being formed by a minute portion of the substance of the meteorite becoming momentarily fused and flowing in a diversified path until cooled. Their course in some cases seems to mark the swirling of the same air currents which formed the pits. More extensive and larger ridges are to be observed over some portions of the crust. Three nearly parallel appear on the portion of the *Rückseite* just mentioned. Each is continuous for a length of from 3 to 5 inches. These do not appear to be of the nature of the lines of flow above mentioned, but more nearly resemble the veins which stand out on some meteorites and probably mark a line of more highly resistant constituents. Sections cut at right angles to the crust and examined with the microscope exhibit little if any alteration on the crust surface. The mineral outlines seem to be continued sharply up to the edge, and except for a certain smoothness of contour a crust surface could not be distinguished microscopically from the surface of an interior portion. Occasionally a metallic grain protrudes from the general outline, but so far as the contour as a whole is concerned it appears to be the result of erosion rather than of fusion.

The weathering which the mass has undergone since its advent upon the earth has affected it considerably. Even the larger fragments when broken open will be found to be deeply invaded by rust which has penetrated along cracks in every direction. Doubtless the great number of small fragments into which the stone was found to be broken when first discovered was due to this process of separation through weathering rather than to shattering caused by the blow of the mass upon the earth. The weathering has affected chiefly the metallic constituents of the stone, causing their oxidation, and this rust has penetrated and stained the meteorite deeply. The color of the weathered surfaces has thus been changed from the dark green of the unaltered rock to various shades of brown, a characteristic color being a light yellowish brown, almost white, spotted with dark or rust brown.

The depth to which this discoloration has extended, except where it has followed cracks and fissures, is usually scarcely a millimeter, the color changing beyond this through reddish to black before the dark green of the unstained stone is seen.

Over a large part of the surface of the stone as found appeared a white amorphous coating which adhered very firmly. It could be removed by treatment with weak acid and most of it has been taken off in this way since the arrival of the stone at the Museum. When its substance is examined chemically it is found to be carbonate of lime containing a small percentage of clay. There can be little doubt that this coating is derived from the calcareous soil in which the stone lay for an unknown period, the carbonate of lime from the soil doubtless spreading over the meteorite surfaces through capillary attraction and cementing upon the stone some of the surrounding clay. In some cavities of the stone a much greater proportion of soil is held, and at many points the cementing agent is iron oxide, derived doubtless from the oxidation of the metallic grains of the meteorite.

The unaltered stone when exposed by fresh fracture is of a dark green color, varying to black, although the latter shade may be due to staining from terrestrial oxidation. The stone is fine-grained, tough and compact. Occasional portions exhibit a slight porosity, giving a slag-like appearance. Such areas are however small and the pores of small size. The proportion of metallic ingredients is not large but they are quite uniformly distributed.

The metallic grains show most plainly on a polished surface, the distribution and quantity being illustrated in Fig. 3. Occasionally well-marked aggregations of these may be seen. None of the surfaces that I have examined show arrangement of the grains in lines or systems of lines such as have been noted in a number of stone meteorites by Reichenbach* and Newton†. The largest metallic grain I have seen in the Long Island meteorite has a diameter of 1.5 mm. From this size all gradations may be found down to the minutest grains, examination with a lens bringing out many not visible to the naked eye.

The bronze-yellow color and comparative softness of many of the grains as exhibited on a polished surface mark them as troilite, in contrast to the silver-white color and greater hardness of those composed of nickel-iron. Further identification of the grains can be obtained by isolating them or by treating a polished surface of the meteorite with copper sulphate. On the polished surfaces examined the number of troilite grains is evidently much in excess of those of nickel-iron.

---

*Ueber das Gefüge der Steinmeteoriten. Poggendorff's Annalen 1859, vol. 108, pp. 291-311.

†Amer. Jour. of Science, 1893, 3rd ser., vol. 45, pp. 152-3.

As individual grains they are, however, smaller in size. Often the nickel-iron and troilite can be seen to be intergrown in a single grain.

Before the blowpipe a fragment of the rock fuses even in the oxidizing flame with a fusibility of about 4.5, the entire fragment blackening from the formation doubtless of FeO. In the reducing flame the fusibility is, as would be expected, greater on account of a more rapid formation of FeO. Evidently the mixture of minerals forms an aggregate fusible at a lower temperature than any of its components, for the component minerals are practically infusible.

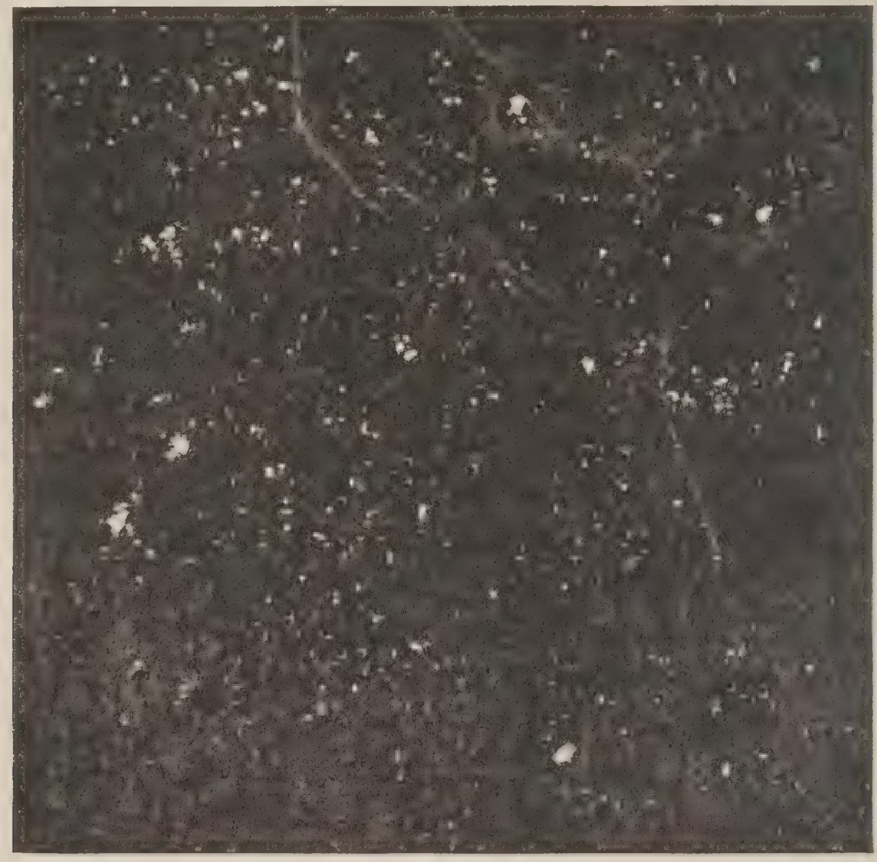


FIG. 3. Polished surface of Long Island meteorite showing size and distribution of metallic grains. Fully half of these are troilite. The light irregular lines mark the position of fractures of no significance. × $\frac{11}{7}$.

The specific gravity of the stone, determined as an average of three separate portions weighing 50, 18 and 7 grams respectively, is 3.45.

As previously stated, a description of the petrographic characters of the stone has been made by Weinschenk*, and as it seems desirable to collect here all the important literature bearing on the meteorite, a translation of Weinschenk's article follows:

"From the Long Island, Phillips County, Kansas, occurrence I

Loc. cit.

have at my disposal four pieces, amounting in weight to 20–30 grams. They possess a rusty weathered surface. Many hundred similar pieces were found (in part with crust), having a total weight of 1,184 pounds. The meteorite of Long Island is a compact, dark stone, which appears dark green on fresh fracture and shows numerous metallic specks. The crystalline structure is megascopically visible; there are numerous shining cleavage surfaces and the meteorite resembles the fine-grained harzburgite from Riddles, Oregon. Chondri are only now and then to be seen. Under the microscope it is clearly seen that chrysolite and bronzite are the characteristic ingredients. The structure as well as the relations in quantity of the two constituents are very variable, the chrysolite now being in excess and now again the pyroxene, and the general porphyritic structure passes commonly enough over to a purely granular one. Chondrus-like forms are found throughout, but they are seldom developed in an especially characteristic way. Ragged particles of metallic iron, numerous grains of iron sulphide (troilite?) and chromite complete its composition. The chrysolite occurs generally in porphyritic, more or less idiomorphic crystals, and in fragments. In the fresh condition it is colorless, but on slight heating it becomes reddish brown and pleochroic, and at red heat completely opaque, indicating a high content of iron. The cleavage of the mineral is always clearly developed, and this shows in many cases undulatory extinction. It is very rich in inclusions, generally appearing as dark-brown rounded forms which often show regular arrangement. In the weathered portions there occurs beside iron hydroxide, a serpentine-like substance as an alteration product of the chrysolite. The orthorhombic pyroxene is likewise colorless and transparent and may be classed as bronzite. It tends to form groups of larger individuals where the stone has granular structure; in smaller crystals it occurs also as a constituent of the ground mass in the porphyritic forms. Its distribution in the stone can best be seen if a section is treated with hydrochloric acid. This dissolves out the chrysolite but leaves the pyroxene unattacked. In sections so treated it can especially well be seen that the bronzite where it occurs as a constituent of the ground mass often exhibits skeleton growths which lie imbedded in a colorless substance and are not attacked by hydrochloric acid. This has weak refraction and between crossed nicols shows irregular illumination so that it is not improbable that it is a glassy substance possessing optical anomalies through strains. Rarely, besides the orthorhombic pyroxene there is to be seen a monoclinic augite in single grains, with the properties of diallage. The solid iron occurs in angular particles and often in zonal growths with chromite which also occurs alone, widely distributed in the stone. The little grains of the latter mineral appear brown, translucent. Also pyrrhotite (*magnetkies*) is present in considerable quantity and generally in large individuals. The structure of the whole stone indicates a cooling from a fused liquid, a view also supported by the porphyritic crystals of chrysolite and the skeletons of bronzite in the colorless base. There is no trace of breccia structure and the occurrence of few well-defined chondri gives no further proof. As has been often observed in meteorites, the whole stone has much more the character of a suddenly cooled mass, a character which is also indicated by the undulatory extinction of the chrysolite, the skeleton growths of pyroxene and the sudden variations in composition. The Long Island meteorite in mineralogical characters belongs to the harzburgites. If among terrestrial rocks we look for masses which in a structural and mineralogical way can be compared to the Long Island meteorite, it will be found that the number is a very limited one for the reason that rocks of similar composition have suffered in most cases much decomposition, by which their structure becomes indeterminable. But at all events it seems probable from the few observations on, for example, the terrestrial basalts of Greenland, that similar structures as they are here observed and in many other meteorites are formations characteristic of cooled rocks in which silicate of magnesia plays an important part, and that no grounds are given for the belief that formations of this kind in any of the terrestrial rocks have originated in any different way."

To the observations of Weinschenk there is little of importance to be added. The crystalline structure is perhaps hardly as prominent megascopically as one would judge from Weinschenk's account, while the chondritic structure is easily recognized in all the sections I have examined. There are numerous polysomatic porphyritic chrysolite chondri and typical fibrous ones of enstatite. One of the latter observed was 2.5 mm. in diameter and it is evidently not cut through its center. A black, seemingly carbonaceous matter, borders its outer edge. The fibers are minute and lie in parallel groups extending in various directions. A porphyritic chrysolite chondrus seen had a diameter of 1.25 mm., a single grain reaching the size of .025 mm. Another monosomatic chrysolite chondrus seen was made up of chrysolite porphyritically developed in glass and with a distinct circular border of chrysolite all extinguishing simultaneously. This chondrus also contained a large grain of troilite. The crystal outlines of the chrysolite individuals whether developed in the chondri or out are often well defined, the predominant habit being short stout crystals bounded chiefly by pinacoids. The chromite more often has a red tone than the brown described by Weinschenk, its deep red grains being frequently seen in the sections. Both nickel-iron and troilite grains sometimes enclose small siliceous particles of what is probably chrysolite, indicating the latter to be the earlier formation.

As regards classification, the Long Island meteorite is classed by Wülfing as a crystalline spherical chondrite, Cck.* Beaver Creek, Bethlehem, Lumpkin, Menow, Prairie Dog Creek, Richmond and Savtschenskoje are other meteorites included in the same class.

Brezina classifies Long Island as a crystalline chondrite Ck.,† in which group are included Erxleben, Klein-Wenden, Kernouve and many others. By Meunier, Long Island is put in Class 34, Erxlebenite, which includes monogenic meteorites of fine grain made up chiefly of chrysolite and bronzite and containing visible grains of nickel-iron. Bluff, Erxleben, Kernouve, Klein-Wenden, Menow and Pipe Creek are among the other meteorites brought by Meunier into this class. Thus the place of Long Island in classification seems to be quite generally agreed upon. Differences can, of course, be noted from other meteorites with which it is classed, it being, for instance, more compact and of finer grain than Beaver Creek and containing much less nickel-iron than Pipe Creek.

Of its well-marked crystalline character, however, there can be no doubt, nor, to my mind, of its monogenic origin.

Absorption by a siliceous magma, of iron in preference to nickel, seems to me to afford a reasonable explanation of the high percentage of nickel in the metallic portion of the stone shown in the following analysis. Such a high percentage of nickel in the nickel-iron of stone as compared with iron meteorites is common and must be of some significance. If the meteorite is simply tuffaceous in origin, one would expect the nickel-iron to have the composition of that of the iron meteorites uninfluenced by the accompanying silicates, but such is not the case.

Again, the outlines of the crystal individuals in the Long Island meteorite are sharply and fully developed and are in stable and magmatic position with reference to each other. Some of them are larger than the individual chondri and yet exhibit no sign of wear or fracture. Accordingly the believers in the tuffaceous character of all stone meteorites would find, I think, little to support their views in an examination of this stone. I can see no indications in its structure of any other origin than one of cooling in place from a fused magma, and this applies to the chondri as well as to every other part of the stone. In this view I agree fully with Weinschenk as quoted above.

---

*Die Meteoriten in Sammlungen, Tubingen, 1897, p. 453.

†Die Meteoriten Sammlung des K.K. Naturhistorische Hofmuseums, Wien, 1895, p. 353.

An analysis of the meteorite was made by Mr. H. W. Nichols, Assistant Curator of the Department, in the laboratory of the Department.

For this analysis a fragment of the meteorite free from visible oxidation was pulverized and dried at 100° C.

A portion of 3.3863 grams was weighed out for the major part of the analysis, experiment having shown that better results could be obtained from portions of this size than from a larger portion of about 16 grams. The nickel-iron was separated by Eggertz's method of solution in iodine, the stone being found to be of too compact a nature to admit of magnetic separation even if the iodine method is not to be preferred in any case. The siliceous portion remaining was separated into two parts in the usual manner by treatment with dilute hydrochloric acid and potash. The separated portions were not weighed as it was found that sufficient oxidation occurred while burning off the filter to vitiate the results, but were analyzed separately and their weights calculated from the analyses. The insoluble portion was fused with sodium carbonate and a small amount of nitre. Silica was determined after the common method. Nickel and cobalt were separated from the iron by three precipitations and long digestion with ammonia and a large excess of ammonium chloride. Cobalt was separated from nickel by potassium nitrite. Nickel was titrated with KCn and cobalt weighed as sulphate. Magnesium was weighed as pyrophosphate and calcium as oxide after an oxalate precipitation in the usual manner. Chromium was weighed as lead chromate after oxidation by bromine in acetic acid solution. Phosphorus was separated by the acetate process and weighed as molybdate. Water above 100°C. was determined in a separate portion by Penfield's method of direct weight. Sulphur was determined in a separate portion as barium sulphate. Iron and insoluble alumina were determined in a separate portion, the iron being titrated by permanganate. The alumina was weighed directly, that of the soluble portion as alumina, that of the insoluble portion as phosphate. The alkalies were determined in a separate portion after separation by platinic chloride as usual. They were found to occur wholly in the insoluble portion. TiO_2 was present in distinct although unweighable quantities. A precipitate of ammonium manganese phosphate also proved to be not quite large enough to weigh. A search for copper gave only a very faint brownish coloration with hydrogen sulphide which was not sufficient to verify.

The analysis gave the following results:

	Metallic.	Sol. in HCl.	Insoluble.	Total.
SiO_2	....	9.11	26.54	35.65
Al_2O_3	....	1.64	1.44	3.08
FeO	....	17.19	5.66	22.85
MgO	....	8.99	13.75	22.74
CaO	....	0.02	1.38	1.40
Na_2O	....	0.00	0.25	0.25
K_2O	....	0.00	0.03	0.03
H_2O above 100°	....	1.52	....	1.52
TiO_2	....	....	Tr.	Tr.
P	....	0.036	0.024	0.060
S	....	1.900	....	1.900
Cr_2O_3	....	0.34	5.99	6.33
NiO	....	0.089	0.68	0.769
CoO	....	0.013	0.047	0.060
MnO	....	Tr.	....	Tr.
Fe	2.60	....	....	2.60
Ni	0.67	....	....	0.67
Co	0.036	....	....	0.036
O for Limonite	....	0.90	....	0.90
	3.31	41.75	55.79	100.85
Less O=S	....	0.95	....	0.95
Less O=P	....	0.06	0.04	0.10
	3.31	40.74	55.75	99.80

The most striking feature of the composition revealed by this analysis is the high percentage of Cr_2O_3. I know of no other meteorite which shows so high a percentage, more than 1 per cent. being rare. Most of this was found in the insoluble portion and may hence be referred to chromite, especially as examination of sections with the microscope shows a large quantity of the red translucent grains which indicate that mineral. It may be worthy of remark, however, that the chromium mineral of the meteorite was more easily decomposed than ordinary chromite. Although left as an insoluble residue after fusion with sodium carbonate, it went into solution on treatment with sulphuric acid without requiring a separate fusion with acid sulphate of potash. The percentage of Cr_2O_3 noted in the soluble portion of the meteorite may probably be regarded as a constituent of the chrysolite, although its quantity here is above the average.

The quantity of Al_2O_3, shown in the soluble portion of the above analysis, is unusually high and is difficult to account for.

although it has not infrequently been reported by other analysts as a constituent of the soluble portion of meteorites.

Grouping the compounds of the above analysis which are known to enter into the composition of nickel-iron, chrysolite and bronzite, the following may be deduced as the probable composition of these three ingredients:

COMPOSITION OF NICKEL-IRON.

	Per Cent.
Fe	78.65
Ni.	20.26
Co.	1.09
	100.00

COMPOSITION OF SOLUBLE SILICATES (CHIEFLY CHRYSOLITE).

	Per Cent.
SiO_2	36.88
MgO	36.40
FeO	18.62
Al_2O_3	6.64
Cr_2O_3	1.38
CaO	0.08
	100.00

Ratio of $2RO:SiO_2::1.9997:1$.

COMPOSITION OF INSOLUBLE SILICATES (CHIEFLY BRONZITE AND MONOCLINIC PYROXENES).

	Per Cent.
SiO_2	56.52
Al_2O_3	3.07
FeO	6.05
MgO	29.28
CaO	2.94
CoO	0.10
NiO	1.45
Na_2O	0.53
K_2O	0.06
	100.00

Ratio of $RO:SiO_2::1:1.0148$.

To place the alkalies in the pyroxenes, as is here done, is contrary to the usual custom, it being common to assume that they are present as feldspars. But as no feldspars could be detected in the slides and as alkalies are known to enter into the composition of pyroxenes in small amount, the conclusion here adopted seems the more reasonable one. No attempt was made to differentiate the two pyroxenes chemically, as I know of no guide for this. The amount of monoclinic pyroxene which can be seen in sections is very small, so that the above can practically be regarded as bronzite. It may seriously be questioned, however, whether digestion in hydrochloric acid can be relied upon to wholly separate the chrysolite and bronzite, for with longer digestion some of the bronzite is apt to go into solution, or, with shorter treatment, some of the chrysolite may not be decomposed. Further investigation of this subject should be made.

Taking all the probable ingredient minerals of the rock into consideration, the following is perhaps the best estimate that can at present be made as to its probable composition:

	Per Cent
Bronzite and Monoclinic Pyroxenes	47.05
Chrysolite	24.74
Limonite	10.50
Chromite	8.83
Troilite	5.24
Schreibersite	0.23
Nickel-Iron	3.31
Oxides of Cobalt and Nickel	0.10
	100.00

Here the limonite is probably of secondary or terrestrial origin and should perhaps be divided up about equally between the nickel-iron and troilite in estimating the pre-terrestrial composition of the rock. The composition as shown above of about one-half bronzite accords well with what one can observe after treating a section with hydrochloric acid so as to dissolve out the chrysolite, for an extensive framework made up of bronzite then remains. The high percentage of chromite indicated by the analysis is also in accordance with observations made with the microscope.

The resemblance of the meteorite to terrestrial peridotites is, as noted by Weinschenk, very marked, and the constant association both in terrestrial and extra-terrestrial regions of the elements and minerals which compose rocks of this class indicates laws of association which are not yet comprehended.

SUMMARY.

1. The Long Island meteorite is a single isolated fall and fell as a single stone.
2. It is the largest single stone meteorite known.
3. It is traversed by planes resembling joint planes which are pre-terrestrial in their origin.

4. In structure it belongs to the class of crystalline chondrites.

5. In chemical composition it is made up chiefly of oxides of silicon, iron, magnesium and chromium, with small percentages of iron, nickel, sulphur and minor constituents.

6. Its mineralogical composition may be estimated as 47% bronzite and some monoclinic pyroxene, 25% chrysolite, 9% chromite, and the remainder nickel-iron, troilite and schreibersite or alteration products of these. The content of chromite is remarkable and the highest yet reported in meteorites.

NESS COUNTY, KANSAS.

MUSEUM No. Me. 490.

Of this fall the Museum possesses one small complete individual having a weight of 85 grams. This aerolite in general form is wedge-shaped with angles but little rounded. Except for one fractured surface it is covered with a black crust or one which was undoubtedly originally all black, but through weathering has taken on in places a rusty brown appearance. The crusted surface is smooth but uneven, the irregularities suggesting pitting, although the depressions are not deep enough to produce pits of definite form. On making a section through the stone and polishing the surface thus exposed, the crust appears as a distinct black border having a thickness of about ¼ mm., in contrast to the dark brown color of the interior of the stone. In texture the crust does not differ noticeably from the interior, the porosity of many meteorite crusts not being in evidence. The dark brown color of the interior of the stone is doubtless largely a discoloration due to weathering. So completely has this discoloration penetrated the stone that it is impossible to find a place where the probable original color remains. The discoloration also makes it impossible to make out much regarding the structure of the stone megascopically, chondri not being visible on a polished surface. Metallic grains are numerous over the polished surface. They are for the most part of small size, the largest that I have noticed not being over 1 mm. in diameter. They consist both of nickel-iron and troilite, the grains of the latter being distinguished by their yellow color and by not taking on a deposit of copper when immersed in copper sulphate. These troilite grains are quite as numerous as the grains of nickel-iron, but never as large.

In texture the stone is compact but it is only fairly coherent, breaking rather easily with a blow of a hammer. The specific gravity of the whole aerolite of 74 grams taken with the balance at 21°C. was found to be 3.504. This value is of course slightly affected by the crust of the stone, but as a fragment without crust weighing 3.4 grams gave the same result the error from this cause must be very small.

Under the microscope the rock is seen to be a crystalline aggregate made up chiefly of grains of chrysolite, bronzite, nickel-iron and troilite. Here and there are traces of a structure which may indicate chondri or fragments of them, but such occurrences are rare. The chondrus-like structures lack definite outline and if of chondritic origin can only be considered fragments. One such fragment seen consists of alternate narrow lamellæ of about equal width, of chrysolite and glass. In another the lamellæ of chrysolite are broader and the mass has a border of chrysolite. Another suggests a portion of a polysomatic chrysolite chondrus. The grain of the stone as a whole is coarse, many of the chrysolite individuals reaching diameters of 0.2 to 0.4 millimeters. These incline to a porphyritic development, although the whole rock is crystalline. The chrysolite individuals are in general considerably seamed and fissured and stained brown from the penetration of iron rust. Where not stained they are colorless except for scattered minute black inclusions which occur in considerable quantity. They occasionally have prismatic outlines but are more often rounded or fragmental. Elongated fibers alternating with glassy or half-glassy lamellæ also occur as previously noted.

A few well-marked aggregations of black, probably carbonaceous matter, occur mixed in a glassy or half-glassy ground mass, the whole having an approximately circular outline, and reaching in one case 0.5 mm. in diameter. Here again a chondritic form is suggested but cannot be positively discerned. The carbonaceous matter is made up of smaller black particles not different from those included in the large chrysolite individuals.

The bronzite usually occurs in the typical fibrous development. It is colorless to yellow, the latter perhaps being due to iron stain.

Quite frequently large grains of an isotropic mineral appear which I cannot yet refer to any species with which I am familiar. The grains are marked by large size and freedom from inclusions and cracks such as characterize the other silicates of the meteorite. One grain seen has 0.7 sq. mm. of surface, another 0.5 sq. mm., while the remainder are smaller. The outline of the grains is irregular and separated from the remaining constituents. Good cleavage is shown in some of the grains and is apparently cubic, although in one individual the planes meet at angles of 50°. The mineral is colorless inclining to a pink tinge. Relief and index of refraction about like that of chrysolite. I hope to give the mineral further investigation when a larger quantity is available.

The metallic grains (nickel-iron and troilite) have more or less angular outlines and incline toward elongated forms. The nickel-iron and troilite are usually intimately joined, although grains of each mineral also occur alone. The troilite, readily recognized by its bronze yellow color, is more abundant than the nickel-iron.

A few opaque grains of black color closely associated with the nickel-iron and troilite are probably to be referred to chromite. Besides these, translucent grains with the typical red color of chromite are numerous, and one observed has a square outline showing it to be a section either of an octahedral or cubic crystal. The chromite always occurs united to the other opaque minerals. The grains of nickel-iron and troilite often enclose grains of silicates of small size.

On the whole the Ness County meteorite should probably be classed as a crystalline chondrite or Meunier's erxlebenite, although its chondritic nature is somewhat doubtful.

As is probably generally known, a number of small aerolites quite similar to the one here described have been found in Ness County. The first of these found was briefly described by Henry L. Ward.* Aside from this description and mention of the stones in one or two catalogues, no further account of them seems to have been published. Since Preston has suggested, however,† that the Ness County stones may belong to the same fall with Kansada, Jerome, Prairie Dog Creek and Long Island, a knowledge of them is desirable as a ground of investigating the suggestion. What additional facts I have been able to gain regarding the Ness County stones in general have been kindly given me by Mr. Henry L. Ward. In all at least twenty-five small aerolites have been found in Ness County, exclusive of Kansada. In weight they range, so far as Mr. Ward has been able to record them, from 34 to 3,467 grams, the total weight being 17,011 grams. This does not represent the entire amount, since of some stones Mr. Ward was unable to obtain exact record, but at least this amount has been found. The majority of these, so far as their place of find has been recorded, have come from the neighborhood of Franklinville, a village about five miles south of Ness City. The first one described by Mr. Ward, however, came from a place nearly twenty miles to the east of Franklinville, the exact locality being given by Mr. Ward as Section 2, Township 20 S., Range 21 W. The village of Wellmanville is not far from this locality and this ærolite may therefore be called the Wellmanville stone.

---

*Amer. Jour. of Science, 4th ser., vol. 7, p. 233.

†Amer. Jour. of Science, 4th ser., vol. 9, p. 112.

For investigating Preston's hypothesis two lines of inquiry may be followed; (1) The probable course of the meteor and (2) the constitution and structure of the stones.

(1) The probable course of the meteor: Starting from Franklinville and going in a general northwest direction the Kansada and Jerome stones will be found nearly in the same line at distances of seventeen miles to Kansada and thirteen miles further on to the locality of the Jerome meteorite.* Thirty miles further on in the same line appears the Oakley find. (See Plate XLV.) That a meteor may have moved along this line dropping fragments as it passed is conceivable, although no observed shower has a greater length of distribution than sixteen miles. If these stones are from a single meteor the direction of movement was undoubtedly from southeast to northwest rather than the reverse, since the smaller fragments would undoubtedly fall first.† The Wellmanville stone is somewhat eccentric to this general course but it is quite conceivable that it may have come from the same meteor so far as the latter's course is concerned. This would give a length of distribution of forty-six miles, or, if the Oakley stone is included, of eighty-six miles. The Long Island and Prairie Dog Creek meteorites evidently lie far outside of this course, although the exact location of the Prairie Dog Creek find seems not to be recorded. Brezina gives it‡ as 39°30′ N., 99°0′ W., on Sappa Creek, Decatur County, Kansas, which is an utterly impossible location. However, Prairie Dog Creek, Decatur County, may be assumed to be its approximate place of find. The Long Island and Prairie Dog Creek locations form then, as shown by Preston, in connection with the Jerome and Ness County stones, a parallelogram 117 miles long by 35 miles broad. This parallelogram extends in a north-northeast direction, a course at about right angles to that which I have just traced. It is

---

* Dana, as quoted by Washington, states that the Jerome meteorite was found on the Smoky Hill River fifteen miles east of Jerome.—Amer. Jour. of Science, 4th ser., vol. 5, p. 447.

† I do not know that attention has been called before to this method of deducing a meteor's course, but it seems evident as a matter of reasoning that the smaller fragments would reach the ground first since the greater momentum possessed by the larger fragments would carry them farther. Meunier is of the opposite opinion (Meteorites, p. 424), but as a matter of record in all showers of which I have been able to obtain statistics the larger stones are found at the farther end of the meteor's path. This was the case at New Concord, Orgueil, Lancé and Butsura. For the purpose of gaining further evidence on this point it is quite desirable that observers should in the future note the weight of the stones in connection with their location when picked up after a meteoric fall.

‡ Die Meteoriten Sammlung, etc., Wien, May 1895, p. 359.

over this area that Preston suggests a meteoric shower might have extended. But an extension of a shower over an area so large, especially in width, would be quite unprecedented so far as present observations go. It seems to me, therefore, from a consideration of the probable paths, that Long Island and Prairie Dog Creek must be regarded as of separate origin from Ness County, Kansada, Jerome and Oakley, but that the four latter may, if only the paths are taken into consideration, belong to the same fall.

(2) The constitution and structure of the stones: On this point, unfortunately, little evidence is as yet at hand. As Preston remarks, the six finds are megascopically very similar. They are all about equally oxidized and coated with carbonate of lime, indicating that they have lain about the same length of time in the soil, and are all of compact texture and possess about the same quantity of metallic grains except Oakley, which contains much more metal than the others. The crust of the large stones is, however, thin and dark-brown in color while that of the small stones (Ness County) is, except Wellmanville, so far as I am able to learn, thick and black. This would indicate some difference in the character of the stones, but perhaps not sufficient to warrant considering them different falls.

From the point of view of structure, Weinschenk states that Prairie Dog Creek is sharply distinguished from Long Island*, for in Prairie Dog Creek the chondri are very numerous and make up the greater part of the stone, while in Long Island the chondri are obscure and the structure has a marked crystalline character. Taking into consideration, therefore, their distance from the other finds and their differences from each other, there seems to be good reason for regarding Prairie Dog Creek and Long Island as separate single falls. Among the remaining four, Oakley, Jerome, Kansada and Franklinville, to which should perhaps be added Wellmanville as distinguished from Franklinville, Oakley seems on the whole to possess a distinguishing character in its larger quantity of metal. According to Preston's determination it contains 14.44% of metal†, presumably nickel-iron, while the percentage of metal (nickel-iron) in Jerome is, according to Washington†, only 4.25%. Oakley is also of coarser grain and possesses more bronzite than Ness County, as I have been able to learn by comparing microscopic sections.

Through the kindness of Dr. Washington I have also been enabled to compare a section of the Jerome meteorite with sections of Oakley and Ness County. Considerable differences are thus brought to light which make it very improbable that Jerome belongs to either of the

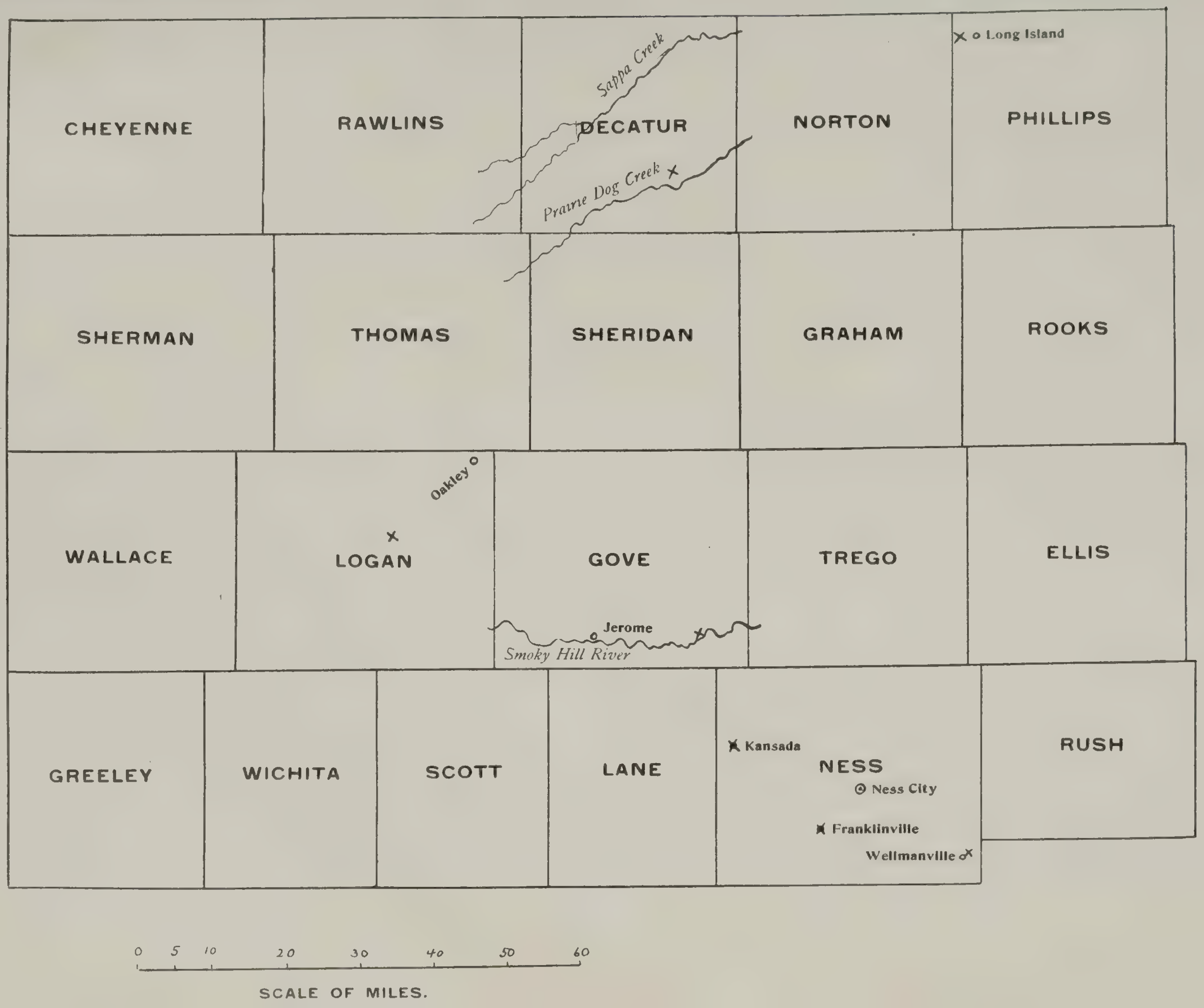
---

*Tschermak's Min. u. Petr. Mitth. vol. 14, p. 474.

†*Loc. cit.*

EXPLANATION OF PLATE XLV.

Map showing location of meteorite finds in counties of northwestern Kansas. × marks location of finds. That of Prairie Dog Creek is approximate only.


CHEYENNE
RAWLINS
DECATUR
NORTON
PHILLIPS
Long Island
Sappa Creek
Prairie Dog Creek
SHERMAN
THOMAS
SHERIDAN
GRAHAM
ROOKS
WALLACE
LOGAN
Oakley
GOVE
Jerome
Smoky Hill River
TREGO
ELLIS
GREELEY
WICHITA
SCOTT
LANE
NESS
Kansada
Ness City
Franklinville
Wellmanville
RUSH
0
5
10
20
30
40
50
60
SCALE OF MILES.

LIBRARY
OF THE
UNIVERSITY of ILLINOIS.

other falls. Its structure is much more highly chondritic than that of either of the above, and the peculiarities of the chondri, which have been so fully described by Washington that they need not here be again enumerated, render them unique. There remain then only Kansada and Wellmanville to be compared as to structure with the other finds. Regarding these two, however, no further data can at present be obtained. No details as to their intimate structure have been published and I do not know the present whereabouts of the stones. It would not be surprising, when an opportunity for comparison presents itself, to find that Kansada could with good reason be connected with either Jerome or Franklinville and Wellmanville with Franklinville. Still, each might prove to be a separate fall, for as may be noted, there is no inherent improbability in supposing falls to take place within a short distance of each other at different times. The falls of Homestead and Hartford, Iowa, were, for instance, separated only about thirty miles and the character of the stones was not very different. The interval of time was twenty-eight years. Castine and Searsmont were separated by only about twenty miles in distance and twenty-three years in time. These are quite similar stones. The Estherville and Forest City falls were distant not over sixty miles from each other and took place within an interval of eleven years. Here, however, the character of the stones was quite different. Doubtless many other instances of falls approaching near each other in space and time could be found by searching. The citing of even the above is, however, sufficient to lead one to the conviction that classing together into one fall meteorites found in different localities is a work that should be performed with caution.

TOLUCA (LOS REYES), MEXICO, D. F.

MUSEUM No. Me. 454.

This meteorite was obtained for the Museum in the spring of 1897 from Mr. E. O. Matthews of the City of Mexico. It was brought him by some native Mexicans or peons who reported that they had found it some months before, at Los Reyes, while ploughing. This is all the evidence obtainable regarding the manner of its discovery. The meteorite is of the metallic variety (áërosiderite) and is a complete individual. Its weight entire is 43 pounds (19.5 kilos). Its form (illustrated by the accompanying cuts, Plate XLVI), is roughly that of a steep triangular pyramid whose greatest length is 24 cm. (9½ inches), and greatest width 15 cm. (6 inches). The sides of the pyramid are deeply hollowed and rounded so that the contours of the mass are curved, and at one of the edges it extends out in the form of a thin wing. On one side near the base are two especially deep and well-marked pits side by side, one somewhat conical in shape, the other broadly concave. The diameter of the conical pit is about 45 mm. (1¾ inches) and its depth 20 mm. (¾ of an inch). The concave pit is about 63 mm. (2½ inches) in diameter and 12 mm. (½ of an inch) deep. These pits (fully shown in Plate XLVI) probably mark areas of schreibersite which were fused out during the passage of the meteorite to the earth. The surface of the meteorite is of a uniform dark brown color from oxidation, but the depth to which oxidation has penetrated is very slight, as the merest scratch with a file reveals the nickel-white color of the interior. The meteorite is not of the "sweating" variety and exhibits no tendency to further alteration.

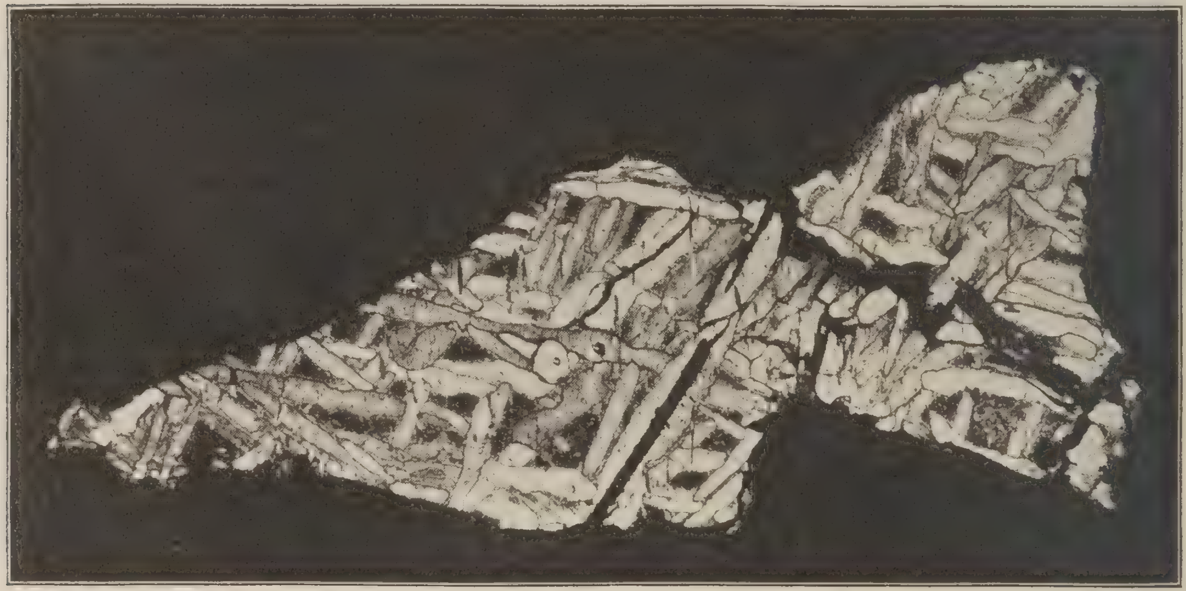


FIG. 4. Etched surface of Toluca (Los Reyes) meteorite, showing character of Widmanstätten figures. × $\frac{3}{2}$.

Its substance is tough and malleable to a high degree. It is medium hard, cutting with some difficulty with a hack-saw. It takes a good polish, a polished surface being of silver-white to nickel-white color. Relative to copper sulphate the meteorite is active.

The iron has not been sliced, but a triangular area 63 mm. x 25 mm. (2½ inches x 1 inch) was made smooth and etched with nitric acid. The surface etched easily and exhibited well-marked Widmanstätten figures which are shown in Fig. 4. Two other smaller surfaces were also etched on other portions of the meteorite. The figures of the meteorite show that it is to be classed with Brezina's group 46 (Octahedrite with lamellæ of medium width) or Meunier's group 7 (Arvaite). The bands of the etching figures are not of uniform

EXPLANATION OF PLATE XLVI.

Front and side views of Toluca (Los Reyes) meteorite. × ½.

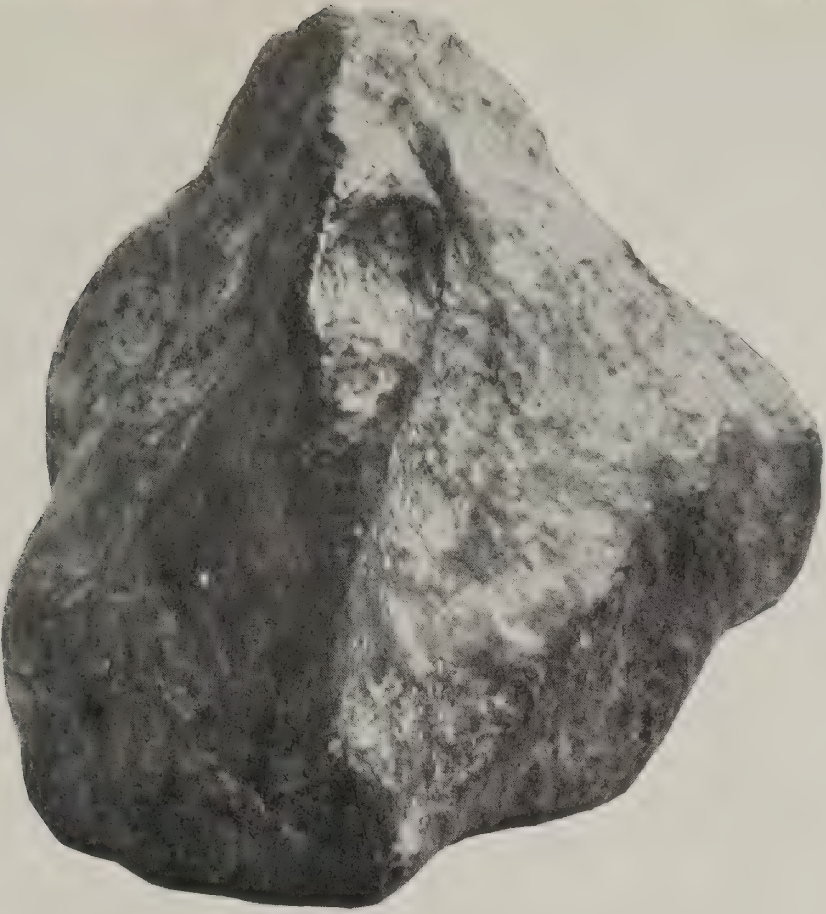


FIG. 1.

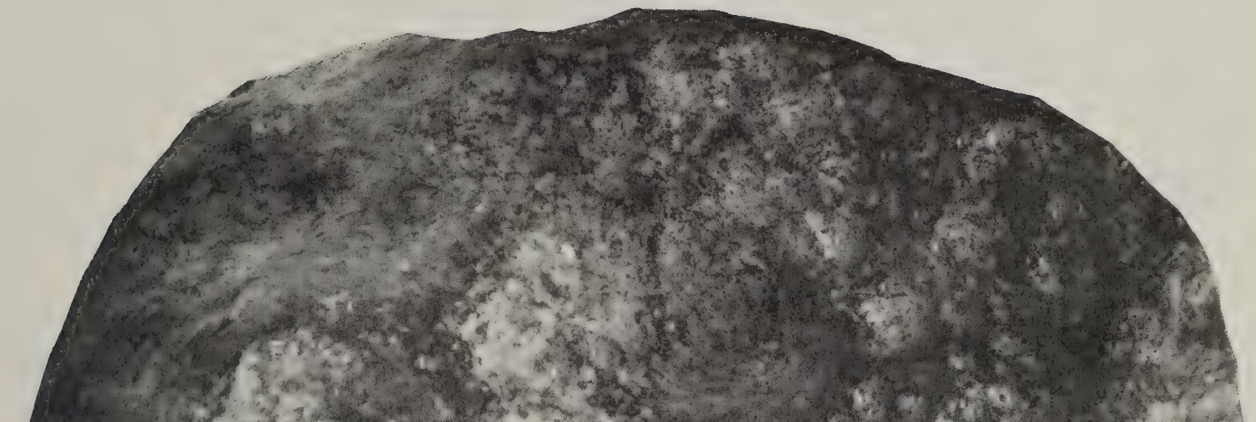


FIG. 2.

LIBRARY
OF THE
UNIVERSITY of ILLINOIS

width nor do they extend continuously for any great distance. They are of the type described by German writers as "*wulstige*" (swollen). The longest one on the etched surface figured accompanying is 11 mm. (5/8) of an inch in length and its contour is very irregular. Only the two alloys kamacite and tænite seem to be present. The former is iron gray in color and occasionally has a well-marked granular structure. The latter, filling the areas between the kamacite bands, is now more or less ribbon-like and now occurs in curvilinear areas. Much of it appears connected through the section, giving the impression of a network in which the kamacite is imbedded. It shades to a bronze color as contrasted with the iron gray of the kamacite and is left standing in relief by the etching. Under the lens its surface appears very rough, the etching of the acid acting upon it more irregularly than upon the kamacite. The only other mineral appearing in abundance in the meteorite is schreibersite, which occurs in long narrow bands or in irregular star-like forms. These areas are bounded by kamacite (swathing kamacite). Decomposition has taken place usually along the schreibersite bands, and these decomposed areas appear as dark marks on the etched surface.

Troilite seems to be almost entirely absent from the meteorite. Only two minute nodules are to be seen on the surfaces which have been etched and the percentage of sulphur obtained by analysis corresponds to a content of only 0.07%. The presence of cohenite is indicated by the carbon found by analysis, but it was not observed on the etched surfaces.

An analysis of the meteorite was made by Mr. H. W. Nichols, the methods employed being briefly as follows: Material for the analysis was secured by a boring made with a 1/4-inch drill. The amount of substance used was 2.4353 grams. In order to prevent loss of sulphur and phosphorus the borings were placed in a flask and first treated with fuming nitric acid, to which they remained passive, and then hydrochloric acid was gradually added cold until solution was complete. Sulphur was weighed as barium sulphate. Phosphorus was determined by Eggertz's method as phosphomolybdate, the quantity being too small to allow of a magnesium pyrophosphate determination. Iron was separated by one ammonia and three basic acetate and one final ammonia precipitation. Manganese was separated by the sodium acetate method. Copper, cobalt and nickel were precipitated as sulphides in acetic acid solution, cobalt and nickel separated by potassium nitrite and all weighed from electrolytic deposition. Carbon was determined in an independent sample by oxidation in chromic acid after the method described by Blair.*

---

*The Chemical Analysis of Iron, 3rd edition, p. 136.

The analysis gave the following results:

Fe	90.56
Ni	7.71
Co	1.07
Cu	0.14
Mn	Trace
P	0.24
C	0.01
S	0.025
Si	0.006
Insol.	0.09
	99.85

Omitting silicon and insoluble matter the analysis indicates that the meteorite has the following mineralogical composition:

Nickel-iron (Fe, Ni, Co, Cu, Mn.)	97.98
Schreibersite	1.55
Cohenite	0.15
Troilite	0.07
	99.75

As the locality where the meteorite was found may be said in a certain sense to be in the vicinity of Toluca, it becomes an important question from the standpoint of the collector to determine whether the specimen is to be regarded a portion of the Toluca fall. Los Reyes is about forty miles (sixty-two kilometers) in a direct line east of Toluca. It is the little station at the southern end of Lake Texcoco where the Morelos division of the Interoceanic Railway joins the main line, about twelve miles southeast of the City of Mexico. On the same line of railroad twenty-five miles from the City of Mexico is the town of Ameca-Ameca, where the find of another iron meteorite has been reported by Castillo.* Castillo classes this iron with the Toluca meteorites,† and describes the "zone" of Toluca meteorites as extending from Ameca-Ameca on the east to Xiquipilco in the valley of Toluca [on the west]. If Castillo is right in this conclusion the Los Reyes meteorite comes within this zone, as Los Reyes is some fifteen miles (twenty-three kilometers) nearer Toluca than Ameca-Ameca. Castillo unfortunately gives no description of the Ameca-Ameca meteorite by which its resemblance or otherwise to the known specimens from Toluca can be determined. He simply describes it as a "small nodule of meteoric iron found in the village [of that name] and now preserved in the National Museum of Mexico." If it is correct thus to group the Ameca-Ameca meteorite (and hence Los Reyes) with Toluca, a distribution of fifty or sixty miles at least must be conceded to this fall, Ixtlahuaca and Xiquipilco, the two localities in the Valley of Toluca where many of the Toluca meteorites are found, being ten miles farther from Ameca-Ameca than Toluca itself. It will be remembered that Fletcher, after a careful study of Mexican meteorites with especial regard to the supposed occurrence of widespread meteoritic showers,* reached a negative conclusion as regards the wide extent of such showers, this opinion being similar to one in regard to such showers in general which he had expressed in an earlier paper.† According to Fletcher the distribution of the Toluca meteorites as they have been reported from localities distant from Toluca was probably due to human agency. With reference to the Ameca-Ameca meteorite he states that "Ameca-Ameca is a town where there are now iron foundries, and where ploughs, castings, smoothing irons, mill wheels and other articles are manufactured," to show that Toluca iron might have been carried there for manufacturing purposes. With regard to this report of the state of manufacturing enterprises in Ameca-Ameca I fear that the distinguished authority of the British Museum has been misinformed, for I have spent weary days in the town without having learned of the existence of such industry.

---

*Catalogue Descriptif des Meteorites du Mexique, Paris, 1889, p. 3.

† *Op. cit.*, p. 11.

The fact brought out by Fletcher to the effect that no *known* meteorite shower has a greater distribution than sixteen miles is a more important one in the study of this case, and the evidence at hand in this instance is hardly sufficient to enable us to assert that the Toluca shower had a wider extent.

The meteorite may of course have reached Los Reyes by the agency of man, but on the whole the indications are that it fell where it was found. The statements of the finders were plain and simple, the meteorite bears no marks showing any attempt to use it for economic purposes, and the price at which it was purchased was lower than any one who had brought it from Toluca would probably have sold it for. If the iron fell where it was found it is important to determine whether it was an independent fall or whether its resemblance to known Toluca irons is sufficient to make it probable that it fell at the time of the Toluca shower. Here again no positive evidence is at hand, but the chances are, in my opinion, in favor of the latter conclusion. The meteorite certainly does not differ sufficiently from known Toluca irons so that its independent origin can be asserted, and on the whole it resembles them considerably. Published analyses of Toluca irons give percentages varying somewhat widely, within which limits the Los Reyes values may certainly be included. For purposes of comparison of analyses, several that have been made of Toluca irons by different authorities are given below:

---

*Mineralogical Magazine, vol. IX, No. 42, pp. 91-179.

†Mineralogical Magazine, vol. VIII, p. 225.

1. Taylor, American Jour. Sci., 3d ser. XXII. 374. 1856.
2 and 3. Pugh, Annal. der Chem. and Pharm. XCVII. 385. 1856.
4. Nason, Jour. Prakt. Chemie. LXXI. 123. 1857.

	Fe	Ni	Co	Cu	Mn	S	C	P	X	
1.	90.72	8.49	0.44	....	....	.....	....	0.18	0.63	= 100.46
2.	90.74	7.78	0.72	0.03	....	0.03	....	0.24	Insol. residue. 0.34	= 99.88
3.	87.89	9.06	1.07	....	0.20	....	....	0.62	X 0.22	= 99.06
4.	90.133	7.241		....	....	Tr.	....	0.376	2.225	= 99.975
Los Reyes	90.56	7.71	1.07	0.14	Tr.	0.025	0.01	0.24	Insol residue. 0.096	99.85

The resemblance in chemical composition to the average of Toluca irons is thus seen to be close. Further, the etching figures come within the limits found in Toluca irons, since these vary considerably in detail as is well known. The meteorite will be designated, therefore, as Toluca (Los Reyes).

HOPEWELL MOUNDS, ROSS COUNTY, OHIO.

MUSEUM No. Me. 480.

Among the objects obtained from the Hopewell Mounds of Ohio, and now in the Anthropological collections of this Museum, are a number made of iron. These include a part of a head and ear ornament, some celts, a number of beads, and lastly a small unwrought mass weighing about 130 grams (5 ounces). Dr. G. A. Dorsey, to whom I am indebted for calling my attention to them, informs me that they were all found associated with a single human skeleton near an altar of one of the mounds. They were considerably oxidized, so that the original metal is in most cases obliterated, but the unwrought mass above mentioned was found to be oxidized only on the surface. A qualitative analysis of some filings from this mass showed the presence of nickel and indicated, as might be expected since no other source of iron probably lay open to the Mound Builders, that the objects were made of meteoric iron. Upon removing the rust from one surface and submitting the area so exposed to the etching action of nitric acid, the meteoric nature of the iron was proved beyond question by the appearance of Widmanstätten figures. The nature of these figures is shown in Figs. 5 and 6, where the structure of bands of kamacite separated by thin ribbons of tænite can be plainly discerned. The width and continuity of the kamacite bands varies considerably. Some are at least a millimeter in width and from these they grade down to not over twice the width of the corresponding tænite ribbon. While many are continuous in a general way for a length of from 10 to 20 millimeters, the tænite runs through them all in a series of anastomosing branches and in places gives the impres-

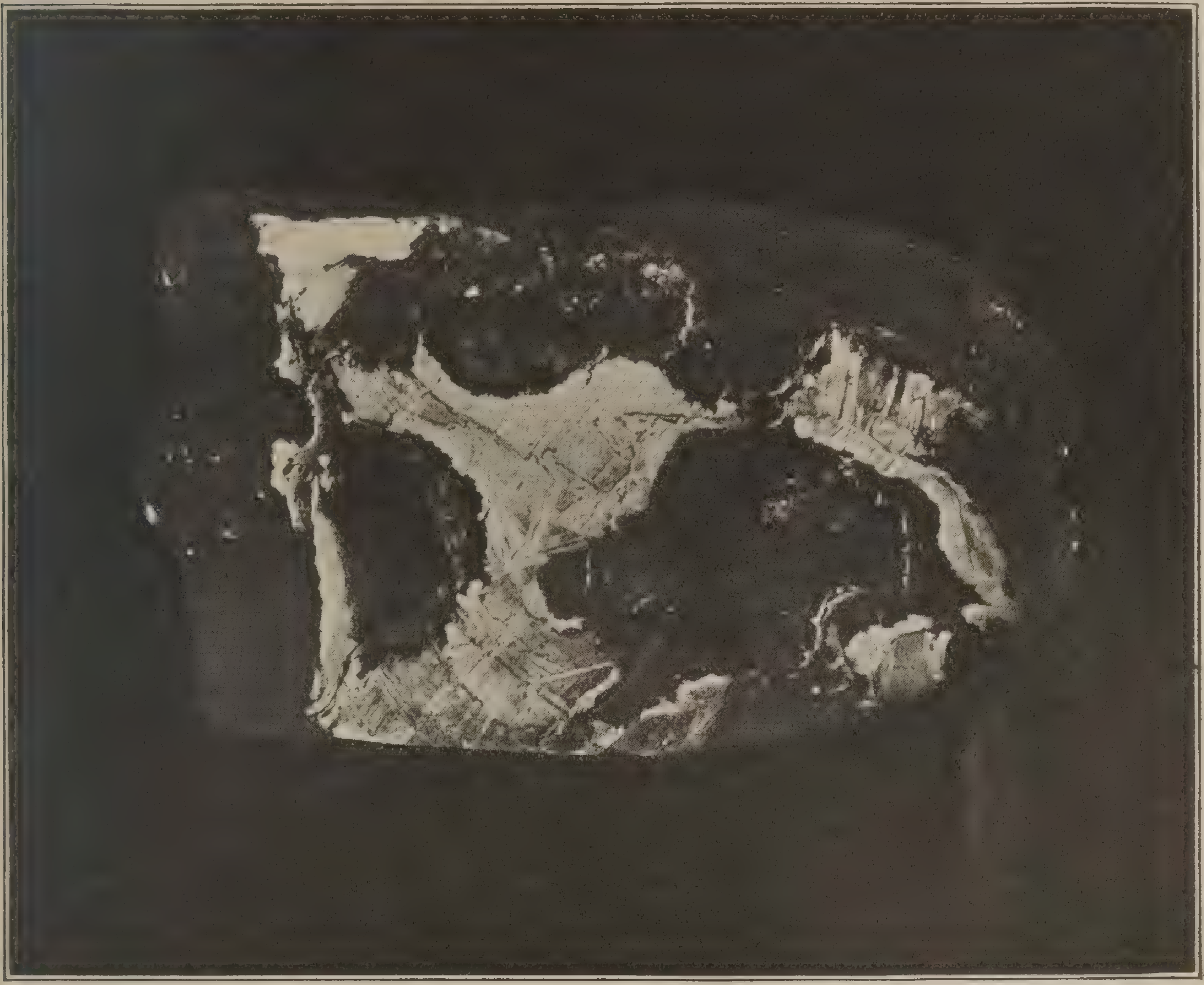


FIG. 5. Outline of Hopewell Mounds meteorite, with etched portions showing curving of the Widmanstätten figures, probably due to heating and hammering that the mass has received. × $\frac{5}{2}$.

sion of a network in which grains of kamacite are imbedded. The contour of the figures is for the most part curved and wavy, especially near the borders of the section. The most reasonable explanation for this seems to be the treatment probably given the mass by the ancient workmen. If heated until it became somewhat plastic and then hammered, just such curving of the plates might be produced. Owing to the distortion of the figures it is impossible to positively classify the iron. Apparently it is an octahedral iron having lamellæ of medium width. While two alloys, kamacite and tænite, are plainly discernible, no troilite or schreibersite can be seen, although the presence of the two latter is indicated by the percentages of sulphur and phosphorus found on analysis. At one end of the mass are three large irregular pores such as might have been produced by the falling out of crystals of chrysolite or other stony matter. There is no other evidence, however, that such stony matter was at one time present and the cavities may have been produced in a purely mechanical way. This seems rather the more probable from the fact that the rest of the mass is quite compact. The iron is rather soft, cutting easily with a hack-saw, and malleable. It is active to copper sulphate.

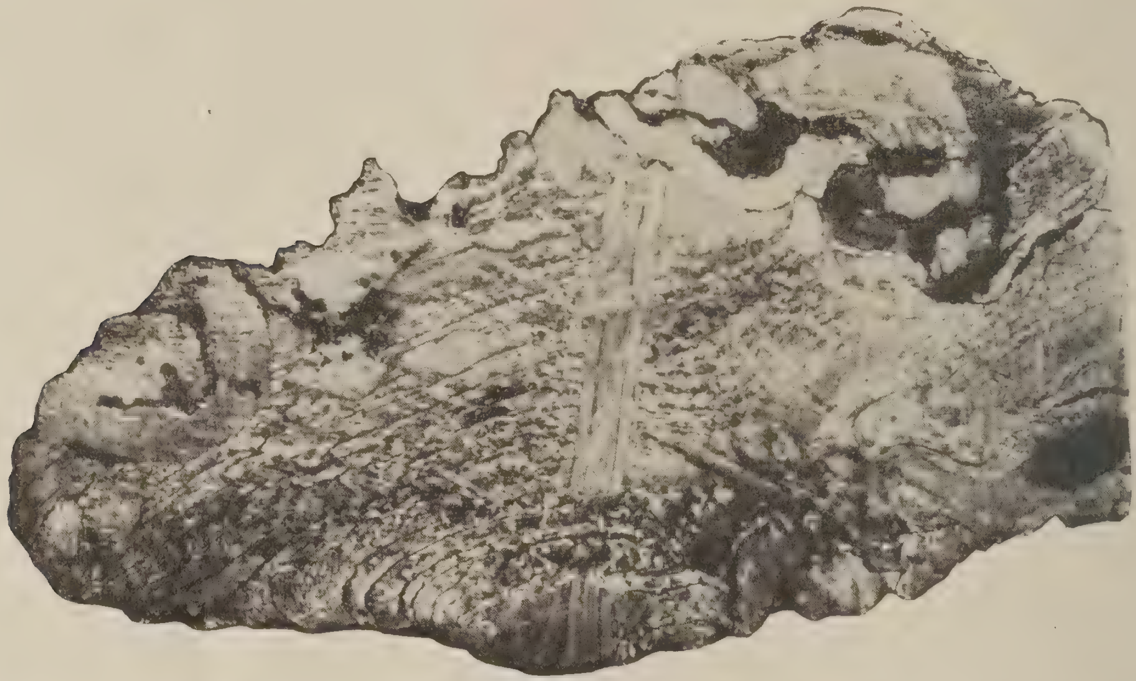


FIG. 6. Etched surface of Hopewell Mounds meteorite showing Widmanstätten figures curved and interwoven, probably on account of heating and hammering that the mass has received. × $\frac{5}{2}$.

For purposes of quantitative analysis a small piece was sawed from one end of the mass and cleaned from rust by filing and scraping.

The analysis, made by Mr. H. W. Nichols, and using the methods noted above for the Los Reyes meteorite, gave the following results:

Amount of substance taken, 2,166.3 grams.

Fe	95.20
Ni	4.64
Co	0.404
Cu	0.035
Mn	trace
Sn	trace
S	0.13
P	0.07
	100.48

The other meteorites known to have been found in Indian mounds of this country are those of Octibbeha County, Mississippi, and the Turner Mounds, Ohio. In the Octibbeha County iron the quantity of nickel reaches 59.7%, and this sufficiently distinguishes it from any other known meteorite. The Turner Mound meteorites include masses from two different mounds, which were analyzed by Kinnicutt* with the following results:

	FROM MOUND NO. 3.		FROM MOUND NO. 4.
	1.	2.	
Fe	86.66	88.37	89.00
Ni	12.67	10.90	10.65
Co	0.33	0.44	0.45

It will be remembered that Kunz concluded from a comparison of the Turner Mounds meteorites with those of Kiowa County, Kansas, that on account of the marked similarity in constitution and structure they belonged to the same fall.* The Hopewell Mounds are only about seventy-five miles distant from the Turner Mounds in an easterly direction, and it might be expected that the same meteoric iron would have been used for the construction of the objects found in these mounds. The results of the analysis above given do not, however, permit this conclusion, the differences in the percentages being greater than are known to occur among the individuals of a single fall. Comparison of etching figures is out of the question on account of the distortion of those of the Hopewell Mounds specimen, but the lack of any content of chrysolite such as characterizes the Turner Mounds

---

*Reports Peabody Museum of Archæology, vol. 3, p. 382, *et seq.*

*American Journal of Science, 3rd series, vol. 40, pp. 316-318.

masses is a further point of difference. It seems impossible at present therefore to connect the Hopewell Mounds mass with any known meteorite and the specimen will therefore be designated as the Hopewell Mounds meteorite.

TAENITE FROM THE KENTON COUNTY METEORITE.

One of the sections of the Kenton County, Kentucky, meteorite in the Museum collection (Museum No. Me. 134), tends to decompose along the planes of structure marked by the Widmanstätten figures. The result of this decomposition is a separation of the mass into fragments bounded by octahedral planes, of a homogeneous alloy of iron-gray color between which lie thin, elastic plates of a tin-white color. The first alloy is undoubtedly kamacite, the second taenite. In order to compare this taenite with that known from other meteorites, some study of it was made. The fragments which it was possible to separate rarely exceeded four square millimeters in surface. As plates, they were thin, elastic and magnetic. The only feature noted regarding their surface was that it is often marked by parallel rows of minute ridges extending across the plate. Corresponding striations usually appear on the adjacent kamacite. The plates are soluble in copper ammonium chloride, and fusible with difficulty B.B.

In separating plates for analysis care was taken to use only those which could be completely isolated and showed no rust. This proved a laborious operation, and after considerable toil the amount that could be secured for analysis was only 0.022 grams. The analysis was made by Mr. H. W. Nichols. Iron was determined by titration with an n/100 potassium bichromate solution, and cobalt and nickel isolated by means of two ammonia and three basic acetate separations and then precipitated electrolytically.

While the extremely small amount used for analysis makes the chances of error larger than is desirable, it is believed that fairly accurate results were attained.

The analysis gave:

Fe	80.3
Ni and Co	19.6
	99.9

This corresponds nearly to the formula $Fe_{13}\ Ni_3$, the percentages for such a compound being:

Fe	80.5
Ni and Co	19.5
	100.00

Other analysts have obtained for the percentages of iron in taenite from other meteorites, values ranging from 86.44% to 57.18%, and corresponding to formulas varying from Fe_6 Ni to $Fe_4\ Ni_3$. Judging from our present knowledge of alloys it is hardly to be expected that taenite should have a uniform composition. Kamacite, being the substance with the lowest freezing point, is to be considered the eutectic of the series and as such has a fairly uniform composition, but this would not be expected of the other alloy or alloys.

INDEX.

Page
Acoustic phenomena of falling meteorites.......9, 11, 14
Aërolites........ 18
Analyses........ 25
Classes........ 24
Definition........ 18
Description........ 23
Aërosiderites........ 18
Analyses........ 19
Definition........ 18
Description........ 18, 22
Aërosiderolites........ 18
Analyses........ 23
Definition........ 22
Description........ 18
Agates, Theory of formation of... 197
Age of the "Pillar of the Constitution"........ 254
Allen, J. A., quoted........ 200
Almy, John D., Communications with........ 221
Altitude of Ixtaccihuatl, various determinations of........ 107
snow line on Popocatepetl... 92
Popocatepetl, Various determinations of........ 87
Altitudes near the Ranch of Tlamacas........ 90
Amagá, Iron mining District of 131, 143
Town of........ 143
Amalfi, Mining District of....131, 137
City of........ 137
Ameca, Town of........78, 308
Ameca-Ameca, same as Ameca.
Amphoterite........ 24
Amyzon shales........ 199
Anaime, Mercury ores of........ 169
Analysis of—dolomite........ 230
Hopewell Mounds meteorite. 313
inesite........ 223
Long Island meteorite........ 297

Page
Analysis of—tænite........ 314
Toluca meteorite........ 308
Analyses of meteorites, quoted 19, 23, 25, 310, 313
Anchitherium........ 185
Andesite, Amphibole, of Ixtaccihuatl........ 119
Hypersthene, of Popocatepetl 100
Anori, History of........ 138
Mining District of.......131, 138
Antioquia, Department of........ 130
District of, West........ 141
Mining districts and ores of.. 130
Anza, Mining District of.131, 141, 142
Aragonite........249, 254
Arsenopyrite, in needle form..... 147
Ascent of—Ixtaccihuatl......104, 105
Popocatepetl........ 82
Asiderites........18, 23
Astrocœnia conica........ 215
Awaruite........ 19
Atlantosaurus........ 281
Baker, Frank C., quoted..86, 105, 111
Ball, S. H........ 181
Bats, Distribution of in caves.... 148
Becker, G. F., quoted........ 265
Bibliography—of Geology of Colombia........ 174
of Popocatepetl and Ixtaccihuatl........ 73
Biela's Comet........29, 30
Bird Remains........ 199
Anatidæ........ 198
Fringillidæ........ 200
Gallæ........ 200
Blatchley, W. S., quoted. 247, 249, 253, 264, 265
Bradbury, Dr. S. M., Correspondence with........ 267
Breccia from weathering of pyrrhotite........ 142

Page
Brongniardite, Occurrence in Colombia of..............156, 157
Brontosaurus 276
Bronzite—of Long Island meteorite 293, 299
  Ness County meteorite...... 301
Bryan, Wm. A., quoted.......... 198
Bustite......................... 24
Calcite, Crystal forms of......... 232
  crystals, Coan's Cave........ 265
  " Joplin.............. 232
  " " Differentiation of surface planes of....... 236
  crystals, Joplin, etching figures 237
  " " Forms of large crystals 233
  crystals, Joplin, Forms of smaller crystals........... 237
  crystals, Joplin, Forms of twinned crystals........... 238
  crystals, Joplin, Localities of large crystals............. 232
  crystals, Joplin, Type I...232, 233
  " " " II..233, 234, 235
  " " " III.... 237
  " " " IV.... 238
  deposited in quiet and moving waters................ 266
  Golden..................... 229
  twins, Joplin................ 238
  " Guanajuato........... 240
  in stalactites.............249, 250
Camarosaurus................... 280
Catalogue of the Meteorite Collection 1
Caledonite..................... 224
  Blowpipe reactions of........ 225
  Crystal forms of............ 225
  Occurrence of.............. 224
Capillary attraction, Influence of on forms of stalactites......... 251
Caramantá, Mining District of.132, 151
Carbonaceous meteorites......17, 27
Castillo, Antonio, quoted 308
Cauca, Mines of.....127, 153, 155, 157
Cave Hill Cemetery, Marengo Cave 257
Caves, Observations on Indiana.. 247

Page
Cenotes 248
Cephalopoda, Development of... 209
Chalcedony.................... 195
Chassignite.................... 24
Cluna River, Mining District of.. 165
Chladnite 24
Chondri 26
  in Long Island meteorite.... 294
  in Ness County " 301
Chondritic Structure 26
Chromite—in Long Island meteorite..293, 294, 295, 297, 299, 300
  in Ness County meteorite.... 302
Chrysolite, Absence of.......... 313
  of Long Island meteorite.293, 298
  of Ness County " 301
Circular Halls in Wyandotte Cave. 247
  Form of 247
  Origin of 247, 248
  Structure of................. 248
Classes of Meteorites........... 18
Cleavage in Meteorites.......... 22
Coal in Colombia........129, 143, 148
Coan's Cave 264
  Bats in 249
  Entrance to................. 264
  Pool in..................... 265
Collection of Ores from Colombia 125
Collections of Ores, Character of ideal 126
Collet, —., quoted............253, 254
Colorado, Grand River Valley of. 267
Colorado ore, defined............ 132
Colombia,
  General Geology............ 128
  Gold production 125
  Mines of 121
  Ores of..................... 121
  Physical features of......... 128
  state of geological science in. 125
  Como Beds.....267, 271, 276, 279
Compounds in meteorites........ 17
Contributions to the Palæontology of the Upper Cretaceous Series 205
Cope, E. D., quoted..181, 183, 185, 200, 281
Copper Ores in Colombia....141, 169
Crater of Popocatepetl..94, 95, 96, 97
  Dimensions of.............. 96

Page
Crystal Cave, Joplin, Mo......... 234
Crystal forms of
  calcite..................229, 232
  caledonite.................. 225
  epsomite.................... 228
  gay-lussite................. 227
  inesite..................... 221
Crystalline structure of meteorites
  19, 21, 293, 295, 301
Crystals, experiments on growth of.......................... 265
Crystals from quiet and moving water, Characters of........... 266
Crust of Meteorites.............. 1
  Long Island Meteorite....... 289
  Ness County Meteorite...... 300
Dakota group of the Grand River Valley...................... 270
Davison, J. M., quoted........... 20
"Diamond Dome," Marengo Cave....................... 259
Dinosaur Beds of the Grand River Valley...................... 267
Diogenite..................... 24
Distribution of—Bats in caves 248, 249
  Meteorites.................. 12
  Sciuromorph rodents........ 187
Dolomite, California............ 231
  used as Indian money....... 230
Dome-shaped Halls in Caves 247, 253
  Form of.................... 247
  Origin of.................. 247
  Structure of............... 248
Dorsey, G. A., On Mines in Colombia....................... 127
  quoted..................230, 310
Dunite........................ 24
Dust spouts in Mexico........... 87
Echandia, Mining District of..... 153
Effects of heat on meteorites 16
Egg, Fossil.................... 193
  Measurement of modern..... 199
Elements in meteorites.......... 16
Elliott, D. G., quoted........... 260
Epsomite...................... 228
Eroded stalactites in Shiloh Cave 262
Erosion in Marengo Cave........ 256
Erosive and solvent action of water in caves................ 248

Page
Etching figures on Calcite....236, 237
  of Meteorites.....20, 21, 306, 311
Eucastor...................... 184
Eutectic of meteorites........... 315
Farrington, O. C., author.
  Crystal forms of Calcite..... 232
  Fossil Egg from South Dak.. 193
  Handbook and Catalogue of the Meteorite Collection... 1
  Meteorite Studies, I......... 283
  New Mineral Occurrences... 221
  Observations on Indiana Caves.................... 247
  Observations on Popocatepetl and Ixtaccihuatl.
Fasciolaria.................... 214
Felix and Lenk, on Ixtaccihuatl.. 104
  on Popocatepetl............ 83
Fissure systems, Wyandotte Cave 248
Fletcher, L., quoted............3, 309
Flos Ferri, Origin of............ 249
Foote, H. W., quoted........... 251
Fore Leg and Pectoral Girdle of Morosaurus.................. 275
"Fortress Monroe," Marengo Cave 257
Fossil Birds.................... 199
  Anatidæ.................... 198
  Fringillidæ................. 200
  Gallæ...................... 200
Fossil Egg..................... 193
  Origin..................... 197
  Resemblance to those of Anatine Birds................. 198
Fossils of the Grand River Valley 272
  Upper Cretaceous Series.... 205
Fossil wood, Organic Matter in... 195
Franklinville meteorite..302, 303, 304
Frias Mine of Guayabal......... 163
  Mining District of.......... 163
Frontino, Mining District of..131, 141
Fusus......................... 215
Gamba, F. Pereira, on Colombian Ores........................ 125
Gay-Lussite.................... 226
  Crystal Forms of........... 227
General conclusions upon the mines and geology of Colombia. 174
Gunnison River................. 268
Heddle, H. Forster, quoted...... 197

Page
"Helen's Dome," Wyandotte Cave 247
Heilprin, Angelo, quoted..80, 106, 111
  Account of ascent by........ 105
Heilprin Peak.................... 112
Hess, Wm. H., quoted........... 249
Holmes, W. H., quoted.......... 248
Hovey, H. C., quoted............ 254
Hyatt, Alpheus, quoted 209
Hystrix refossa.................. 183
Ibague, City of................... 167
  Mining District of........... 167
Iddings, J. P., loan of crystals by. 232
Index to meteorites mentioned in Museum Handbook and Catalogue 62
Indiana Caves, Observations on.. 247
Indian Money.................... 230
Inesite. 221
  Analysis of................. 222
  Blowpipe reactions of....... 221
  Forms of.................... 221
  Formula of.................. 224
  Localities of................ 221
Iron Ores, in Colombia.......... 143
Ixtaccihuatl, Observations on.... 67
  Glacier on.................. 111
Jaguas, defined 147
Jamesonite...................148, 150
Jerome meteorite........302, 303, 304
Joint planes in Long Island meteorite......................... 286
Joplin, Mo., Calcite from......... 232
Jurassic Strata of the Grand River Valley 269
Kamacite, Composition of....... 17
  in Hopewell Mounds meteorite........................ 311
  " Kenton County meteorite. 314
  " Toluca meteorite......... 306
  Nature of................... 20
Kansada meteorite......302, 303, 304
Kenton County meteorite, Analysis of taenite from 314
Kermesite....................... 152
Knight, Prof. W. C., Communications from.................227, 228
Kunz, Geo.. F., Meteorites purchased from..............8, 34
  quoted...................... 285

Page
La Plata del Libano, Mines of... 165
Leaf Stalactites................. 262
Libano, Mining Districts of...... 165
Limit of Vegetation on Popocatepetl......................... 92
Loaiza Hill, Silver Mines of..... 153
Logan, Wm. N., author, Contributions to the Palæontology of the Upper Cretaceous Series...... 205
Long Island meteorite,
  Analysis of 297
  Catalogue of................ 59
  Description of.............. 285
  Occurrence of............... 283
Los Reyes, Find of meteorite in.. 305
  Location of................. 308
Ludwig and Soret, quoted....... 265
Magdalena River, Geology of.... 159
Mammoth Cave, Rotunda in..... 247
Manizales, City of............... 156
  Mining District of........... 156
Map of—Antioquia and Tolima.. 177
  meteorite falls in Northwestern Kansas............... 304
  Popocatepetl and Ixtaccihuatl 120
Marengo Cave.................. 256
  Abundance of stalagmites in 257
  Floor terrace in............. 256
  Origin of peculiar stalagmites in.................. 257
  Rate of growth of stalagmites in 261
  Stalagmo-Stalagmites in..... 259
  Stream deposit in........... 257
Mariquita, Ancient City of....... 159
Marmato, Mining District....... 153
Marsh, O. C., quoted............ 275
Matthews, E. O., Meteorite obtained from.................. 305
Measurements of—eggs......... 199
  Morosaurus bones.......278, 279
Medellin, City of................ 140
Meek, F. W., quoted............ 211
Meniscomys hippodus........... 183
Menke, H. W., Photographs by 191, 267
Mercury ores in Colombia....... 169
"Mermaid," Marengo Cave...... 259
Merrill, G. P., quoted....249, 251, 254

Page
- Mesogaulus..............184, 185, 186
  - ballensis.................... 181
  - monodon 181
  - sesquipedalis 181
- Meteorites, Handbook and Catalogue of.................. 1
  - Studies of 283
- Meunier, S., quoted.....288, 295, 303
- Milne, Sir Alexander, quoted.... 255
- "Milroy's Temple," Wyandotte Cave........................ 247
- Molecular arrangement of stalagmites and stalactites 260
- Molino ore. 154
- Money, Indian.................... 230
- "Monument Mountain," Wyandotte Cave 248
- Moraine of Porfirio Diaz Glacier. 115
- Morosaurus agilis................ 275
  - Fore Leg and Pectoral Girdle of 275
  - grandis.........275, 276, 278, 279
  - impar 275
  - lentus 275
  - robustus 275, 280
- Morton, Nye F., on the ores of Antioquia 130
- "Mount Vesuvius," Marengo Cave 259
- Mylagaulidæ.................... 181
  - Phylogeny of............... 184
- Mylaugaulus 181
- Ness County Meteorites......... 300
- New Mineral Occurrences....... 221
- Nichols, H. W., Analyses by..296, 307, 313, 314
  - Author, Ores of Colombia.... 121
  - Collections by............. 232
  - Experiments by............. 265
- Nitrates in cave earths.......... 249
- Oakley meteorite............303, 304
- Observations on Indiana Caves.. 247
  - Popocatepetl and Ixtaccihuatl 67
- "Odd Fellow's Hall," Wyandotte Cave......................... 247
- Ores of Colombia............... 121
- Organic matter in fossils 195
- Origin of—stalagmites in Marengo Cave..................... 257
  - ores in tuff 149

Page
- Osborn, H. F., quoted.......276, 281
- Ostrea 213
  - Distribution of............. 213
  - beloiti..................... 214
- Packard, A. S., quoted....77, 86, 103
- Palache, Chas., Communication from 239
- Pamplona, City of 170
  - Mines of 170
- Peale, A. S., on the Jurassic of the Gunnison Valley...........267, 270
- Pectoral girdle of Morosaurus... 275
- Petrified wood, Organic matter in........................... 195
- Petrography of—Ixtaccihuatl.... 119
  - Long Island meteorite...... 293
  - Ness County meteorite...... 301
  - Popocatepetl 100
- Phylogeny of the Mylagaulidæ.. 184
- Physical features of Colombia.... 128
- Pico del Fraile................94, 99
- "Pillar of the Constitution"...... 252
  - Age of..................... 254
- Pirsson, L. V., quoted........... 240
- Pits on meteorites....13, 289, 300, 306
- Po (Indian money) 231
- Popocatepetl, Ascents of......79, 82, 83, 84, 85, 86
  - Description of............. 80
  - Observations on 67
- Porfirio Diaz Glacier........... 111
  - Collecting ground of 112
  - Evidences of former extent of. 115
  - Middle ground of.......... 113
  - Terminal portion of........ 114
  - " moraine of 115
- Prairie Dog Creek meteorite..303, 304
- Preston, H. L., quoted.......... 302
- Prestwich, J., quoted........... 256
- Prionotropis woolgari.......... 211
- "Prison Cell," Marengo Cave.... 257
- Protogaulus hippodus.......... 183
- Pseudoperna wilsoni........... 215
- Pyrargyrite.....156, 158, 160, 164, 166
- Quiuna, Gold mine of.......... 142
- Randolph, John C., on Colombia 159, 164
- Reclus, Elisée, quoted...143, 160, 173

Page
Remedios, City of................ 132
  Mining District of.......131, 132
Restrepo, Vicente, quoted....144, 162
Riggs, E. S., author, Dinosaur Beds of the Grand River Valley of Colorado......... 267
  Fore Leg and Pectoral Girdle of Morosaurus............ 275
  The Mylagaulidæ........... 181
Robertson's Cave............... 258
"Rock of Gibraltar," Marengo Cave......................... 257
Rodents, Distribution of Sciuromorph....................... 187
Rothrock, H. A..............253, 254
"Rothrock's Cathedral," Wyandotte Cave................... 247
"Rotunda," Mammoth Cave..... 247
"Sand Pit," Marengo Cave...... 257
San Pedro Mining District...131, 140
San Sebastian de la Plata........ 159
Santa Ana Mine, History of...... 162
Santana, Mining District of...... 163
Santa Rosa de Osos, City of...... 139
  Mining District of.......131, 139
Scaphites....................... 207
  Distribution of............. 207
  nodosus.................... 209
  œqualis.................... 207
  Ontogeny.................. 208
  Paleontogeny............... 208
  Phylogeny.................. 208
  ventricosus................ 211
  warreni.................... 209
    " revised and enlarged description of............. 210
Scheiderz, defined................ 196
Schlemm, W. H. 221
Schreibersite..........17, 19, 22, 307
Sciuromorph Rodents, Distribution of......................... 187
Scott, W. B., quoted............. 181
"Senate Chamber," Marengo Cave..................247, 248, 252
Senft, F., quoted.....249, 250, 254, 257
Shiloh Cave..................... 262
  Eroded stalactites in........ 262
  Leaf stalactites in........... 262
  Stalagmo-stalagmite from... 259

Page
Sierra de Ahualco............73, 75
  Route to the Mountains of... 77
  Former fauna of............ 76
    " glaciation of........ 77
  Time of origin of............ 76
  Lavas of..................76, 77
Sigmogomphius 184
Slickensides,
  in Long Island meteorite.... 288
  in meteorites 27
  Origin of................... 288
Snow Line, altitude of on Popocatepetl....................... 92
Soledad, Mining District of...... 161
Specific gravity,
  of fossil egg................ 196
  of inesite.................. 223
  of Long Island meteorite.... 292
  of meteorites in general..19, 23, 26, 39
  of Ness County meteorite.... 301
Stalactites, Eroded 262
  Leaf....................... 262
  Molecular arrangement of... 260
  Modified by capillary action. 251
  Vermiform 249
Stagmalites, Definition of........ 261
  Rate of growth of.......... 261
Stalagmites, Abundance of in
    Marengo Cave............ 257
  Bermuda.................. 255
  Origin of.................. 258
  Molecular arrangement of... 260
  from Robertson's Cave...... 258
  Variations in the form of.... 258
Stalagmo-stalactites............. 259
Stephanite in Colombia......... 156
Stibnite in Colombia 151, 152, 158, 161
Stratigraphy of the Grand River Valley....................... 268
Stream deposit in Marengo Cave 257
Subcarboniferous strata in Tolima 129
Subcarboniferous limestone from Santander................ 129
Sucre, Mining District of........ 161
Sulphur Mines on Popocatepetl 89, 90
Supia, Mining District of........ 155
Syenite, Use of the term in Colombia........................... 133

Page
Taenite, Analysis of from Kenton County meteorite 314
Composition of 17, 315
Description of 20, 307, 312
Tellurides of gold in Colombia .. 141
Terminal Moraine, Porfirio Diaz Glacier....... 115
Terrace on cave floor 256
Thames, Rate of erosion by 256
Thumbmarks of meteorites..... .. 14
Titiribi, City of 144
Mining District of.......132, 144
Origin of ores of........ .. 149
Tolima, Department of.......... 159
Mining Districts and ores of. 159
Volcano of 160
Toluca meteorites, Analyses of, quoted 310
Distribution of..... 308
Triassic strata of the Grand River Valley 268
Troilite...........17, 22, 291, 302, 307
Turner Mounds meteorite, Analyses of, quoted.... 313
Uncompahgre Plateau 267
Upper Cretaceous Series, Palæontology of................. 205
Venadillo, Mining District of.... 167
Vermiform stalactites.......... 130
Vetas de cajon..............130, 139
Viviparus...................... 272
Volcano of Popocatepetl........ 80
Volcano of Tolima............. 160
Ward's Natural Science Establishment, Meteorites obtained from.......................8, 34
Ward, Henry L., quoted......... 302
Washington, H. L., Loan of section by 304
quoted 303
"Washington's Monument," Marengo Cave 258
Weinschenk, E., quoted......292, 304
Weller, Stuart 209
Wellmanville meteorite..303, 304, 305
Western Antioquia Mining Districts....................131, 141
Widmanstätten figures, Description of................20, 21
of Hopewell Mounds meteorite 311
of Toluca meteorite......... 306
Weyman, Henry, on Crystal Cave.. 234
White, Robert, on petrography of Colombia.................... 129
Willard, J. T., quoted........... 283
Williston, S. W., quoted......267, 283
Wyandotte Cave, Circular halls in 247
Distribution of bats in....... 248
Fissure systems of.......... 248
"Pillar of the Constitution" in 252
Vermiform stalactites in..... 249
Zancudo Establishment......144, 145

PRESERVATION REVIEW
08/04

UNIVERSITY OF ILLINOIS-URBANA
3 0112 062146433